THE CITY OF SAN DIEGO

Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall 2007

City of San Diego Ocean Monitoring Program

Metropolitan Wastewater Department
Environmental Monitoring and Technical Services Division

THE CITY OF SAN DIEGO
MAYOR JERRY SANDERS

June 30, 2008

Mr. John Robertus
Executive Officer
Regional Water Quality Control Board
San Diego Region
9771 Clairemont Mesa Blvd. Suite B
San Diego, CA 92124

Attention: POTW Compliance Unit

Dear Sir:

Enclosed is the 2007 Annual Receiving Waters Monitoring Report for NPDES Permit No. CA0107409, Order No. R9-2002-0025 for the City of San Diego Point Loma Wastewater Treatment Plant, Point Loma Ocean Outfall. This report contains data summaries and statistical analyses for the various portions of the ocean monitoring program, including oceanographic conditions, microbiology, sediment characteristics, benthic macrofauna, demersal fish and megabenthic invertebrate communities, and bioaccumulation of contaminants in fish tissues.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering information, I certify that the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Sincerely,

ALAN C. LANGWORTHY
Deputy Metropolitan Wastewater Director

ACL\ag
Enclosure

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for the
Point Loma Ocean Outfall
2007

Prepared by:

City of San Diego
Ocean Monitoring Program
Metropolitan Wastewater Department
Environmental Monitoring and Technical Services Division

June 2008

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FOR THE POINT LOMA OCEAN OUTFALL
2008

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Cover Photo: Common dolphin, *Delphinus delphis*. Photo by Nick Haring.

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Executive Summary

The monitoring and reporting requirements for the City of San Diego (City) Point Loma Wastewater Treatment Plant (PLWTP) are outlined in NPDES Permit No. CA0107409 and Monitoring and Reporting Program No. R9-2002-0025. The main objectives of the Point Loma ocean monitoring program is to assess the impact of wastewater discharged through the Point Loma Ocean Outfall (PLOO) on the marine environment off San Diego, provide data that satisfy NPDES permit requirements, demonstrate compliance with the 2001 California Ocean Plan (COP) as specified in the above permit, monitor dispersion of the waste field, and identify any environmental changes that may have occurred. Specifically, the program was designed to assess the effects of wastewater discharge on ocean water quality, sediment conditions and marine organisms. The study area is centered around the PLOO discharge site, which is located approximately 7.2 km offshore of the PLWTP at a depth of nearly 100 m. Monitoring at sites along the shore extends from Mission Beach southward to the tip of Point Loma, while offshore monitoring occurs in an adjacent area overlying the coastal continental shelf at sites ranging from 9 to 116 m in depth.

Prior to the initiation of wastewater discharge through the extended outfall in late 1993, the City conducted a 2½-year baseline study designed to characterize background environmental conditions in the Point Loma region in order to provide information against which post-discharge data could be compared. Additionally, each year the City also typically conducts a region-wide survey of benthic conditions at randomly selected sites from Del Mar to the Mexico border as part of NPDES requirements for the South Bay Water Reclamation Plant. Both of the above types of studies are useful for evaluating patterns and trends over a broader geographic area, thus providing additional information to help distinguish reference areas from sites impacted by anthropogenic influences.

The receiving waters monitoring effort for the Point Loma region is divided into several major components, each comprising a separate chapter in this report: Oceanographic Conditions, Microbiology, Sediment Characteristics, Macrobenthic Communities, Demersal Fishes and Megabenthic Invertebrates, and Bioaccumulation of Contaminants in Fish Tissues. Chapter 1 presents a general introduction and overview of the ocean monitoring program for the Point Loma outfall region. In Chapter 2 monitoring data regarding various physical and chemical oceanographic parameters are evaluated to characterize water mass transport potential in the region. Chapter 3 presents the results of water quality monitoring conducted along the shore and in offshore waters, which includes the measurement of bacteriological indicators to assess potential effects of both natural and anthropogenic inputs, and to determine compliance with 2001 COP water contact standards. The results of benthic sampling and analyses of soft-bottom sediments and their associated macrofaunal communities are presented in Chapters 4 and 5, respectively. Chapter 6 presents the results of trawling activities to assess the status of bottom dwelling (demersal) fish and megabenthic invertebrate communities. Bioaccumulation studies to determine whether contaminants are present in the tissues of local fishes supplement the monitoring of demersal fish populations and are presented in Chapter 7. In addition to these activities, the City supports other projects relevant to assessing ocean quality in the region (see Chapter 1). One such project is a remote sensing study of the San Diego and Tijuana coastal regions. These results are incorporated herein into the interpretations of oceanographic and microbiological data (see Chapters 2 and 3).

The present report focuses on the results of all ocean monitoring activities conducted in the Point Loma region during 2007. An overview and summary of the main findings for each of the major component of the monitoring program are included below.

Analysis of the receiving waters monitoring data off San Diego indicates that the PLOO has had only a limited effect on the local marine environment after 14 years of wastewater discharge at the present location. For example, water samples collected at sites within the Point Loma kelp bed were 100% compliant with 2001 COP bacterial water-contact standards in 2007. Compliance with COP standards was also very high along the shore, with all but two stations being 100% compliant during the year. Shore stations D8 and D11 were the only stations with seawater samples where bacteria levels fell below 100% compliance. Station D8, located near a tidally influenced storm drain, was 78% compliant with the 60-day fecal coliform standard, 92% compliant with the fecal geometric mean standard, and 100% compliant with the other two COP standards. Station D11, located near the mouth of the San Diego River, was 92% compliant with the 60-day fecal coliform standard and 100% compliant with the other three COP standards. Elevated bacterial concentrations in offshore waters that could be attributable to wastewater discharge were mostly limited to depths of 60 m or below. Three samples from shallower waters that were indicative of contaminated water occurred south of Point Loma and were likely related to non-outfall sources. Additionally, there was no evidence that the waste field from the outfall reached or affected any shoreline station in 2007, which is consistent with previous findings since the outfall was extended to the present deep discharge site.

Overall, there continues to be no evidence of change in any physical or chemical water quality parameter such as dissolved oxygen or pH that can be attributed to the discharge of wastewater off Point Loma. Instead, historical changes in these parameters have primarily been associated with natural events such as storm activity and the presence of phyoplankton blooms. Finally, drought conditions for the San Diego region that began in late 2005 continued into 2007, thus resulting in reduced runoff of storm water or other inputs to coastal waters (e.g., river flows) during the year. Consequently, fewer turbidity plumes were observed along the San Diego coast relative to wetter years such as in 2005, with ocean waters in the PLOO region generally appearing clearer throughout 2007.

Benthic conditions off Point Loma continued to show some changes in 2007 that may be expected near large ocean outfalls, although these were restricted to a relatively small, localized region within about 300 m of the outfall. For example, sediment quality data have indicated slight increases over time in terms of sulfide and BOD concentrations at sites nearest the Zone of Initial Dilution (ZID), an area where relatively coarse sediment particles have also tended to accumulate. However, other measures of environmental impact such as concentrations of sediment contaminants (e.g., trace metals, pesticides) showed no patterns related to wastewater discharge. Some descriptors of benthic community structure (e.g., infaunal abundance, species diversity) or indicators of environmental disturbance (e.g., brittle star populations) have shown temporal differences between reference areas and sites nearest the ZID. However, results from environmental disturbance indices such as the BRI (benthic response index) that are used to evaluate benthic conditions suggest that macrofaunal communities in the Point Loma region remain characteristic of natural conditions. Analyses of bottom dwelling (demersal) fish and trawl-caught megabenthic invertebrate communities during the past year also reveal no spatial or temporal patterns that can be attributed to effects of wastewater discharge. Additionally, a review of long-term data from 1991 through 2007 indicates that patterns of change in fish assemblages appear related to large-scale oceanographic events (e.g., El Niño) or proximity to other contaminant sources (e.g., dredge material disposal sites). The paucity of pathological evidence from local fishes and the results of bioaccumulation studies also suggest that local fish assemblages remain healthy and are not adversely affected by wastewater discharge or other anthropogenic inputs. Consequently, there is currently no evidence of significant long-term negative impacts on water quality, sediment quality, or biotic communities in the coastal waters surrounding the Point Loma outfall off San Diego.

Chapter 1. General Introduction

INTRODUCTION

Treated effluent from the City of San Diego's Point Loma Wastewater Treatment Plant (PLWTP) is discharged to the Pacific Ocean through the Point Loma Ocean Outfall (PLOO) according to requirements set forth in Order No. R9-2002-0025, National Pollutant Discharge Elimination System (NPDES) Permit No. CA0107409. The above Order and associated Monitoring and Reporting Program (MRP No. R9-2002-0025) were adopted by the San Diego Regional Water Quality Control Board (RWQCB) on April 10, 2002. During 2003, MRP requirements for the Point Loma region were further modified with the adoption of Addendum No. 1 to the above Order and NPDES Permit (see City of San Diego 2004). The provisions established in Addendum No. 1 became effective August 1, 2003, thus superseding and replacing all prior receiving waters monitoring requirements for the PLWTP.

The MRP for Point Loma defines the requirements for monitoring the receiving water environment around the PLOO, including the sampling plan, compliance criteria, laboratory analyses, and data analyses and reporting guidelines. The main objectives of the ocean monitoring program are to provide data that satisfy the requirements of the NPDES permit, demonstrate compliance with the provisions of the 2001 California Ocean Plan (COP) as specified within the NPDES permit, detect movement and dispersion of the wastewater field, and identify any biological or chemical changes that may be associated with wastewater discharge.

Background

The City of San Diego began operation of the PLWTP and original ocean outfall off Point Loma in 1963, at which time treated effluent was discharged approximately 3.9 km offshore at a depth of about 60 m (200 ft). From 1963 to 1985, the plant operated as a primary treatment facility, removing approximately 60% of the total suspended solids (TSS) by gravity separation. Since then, considerable improvements have been made to the treatment process. The City began upgrading the process to advanced primary treatment (APT) in mid-1985, with full APT status being achieved by July of 1986. This improvement involved the addition of chemical coagulation to the treatment process, and resulted in an increased TSS removal of about 75%. Since 1986, treatment has been further enhanced with the addition of several more sedimentation basins, expanded aerated grit removal, and refinements in chemical treatment. These enhancements have resulted in lower mass emissions from the plant. TSS removals are now consistently greater than the 80% permit requirement.

In addition, the PLOO was extended 3.3 km further offshore in the early 1990s in order to prevent intrusion of the wastewater plume into nearshore waters and improve compliance with standards set forth in the COP for water-contact sports areas. Construction of the outfall extension was completed in November 1993, at which time discharge was terminated at the original 60-m site. The outfall presently extends approximately 7.2 km offshore to a depth of 94 m (310 ft), where the pipeline splits into a Y-shaped multiport diffuser system. The two diffuser legs extend an additional 762 m to the north and south, each terminating at a depth of about 98 m (320 ft) near the edge of the continental shelf.

The average daily flow of effluent through the PLOO in 2007 was 161 mgd, ranging from 142.8 mgd in November to 205.5 mgd in February. This is about 5% lower than the 2006 average flow of 170 mgd. TSS removal averaged about 89% during 2007, with a total mass emissions of approximately 7,577 mt/yr relative to 8,211 mt/yr in 2006 (see City of San Diego 2008a).

Receiving Waters Monitoring

Prior to 1994, the City conducted an extensive ocean monitoring program off Point Loma surrounding the original 60-m discharge site. This program was subsequently modified and expanded with the construction and operation of the deeper outfall. Data from the last year of regular monitoring near the original inshore site are presented in City of San Diego (1995b), while the results of a 3-year "recovery study" are summarized in City of San Diego (1998). From 1991 through 1993, the City also conducted a voluntary "pre-discharge" study in the vicinity of the new site in order to collect baseline data prior to the discharge of effluent in these deeper waters (City of San Diego 1995a, b). Results of NPDES mandated monitoring for the extended PLOO from 1994 through 2006 are available in previous annual receiving waters monitoring reports (e.g., City of San Diego 2007). In addition, the City has conducted annual region-wide surveys off the coast of San Diego since 1994 either as part of regular South Bay monitoring requirements (e.g., see City of San Diego 1999, 2008c) or as part of larger, multi-agency surveys of the entire Southern California Bight (e.g., Allen et al. 1994, 2002, 2007, Bergen et al. 1998, 2001, Schiff and Gossett 1998, Noblet et al. 2003, Ranasinghe et al. 2003, 2007, Schiff et al. 2006). Such large-scale surveys are useful in characterizing the ecological health of diverse coastal areas and may help to identify and distinguish reference sites from those impacted by wastewater or stormwater discharges, urban runoff, or other sources of contamination.

The current sampling area off Point Loma extends from the shoreline seaward to a depth of about 116 m (380 ft) (**Figure 1.1**). Fixed sites are generally arranged in a grid surrounding the outfall and are monitored in accordance with a prescribed sampling schedule. Results of relevant quality assurance procedures for the receiving waters monitoring activities are included in the EMTS Division Laboratory Quality Assurance Report (City of San Diego 2008b). Data files, detailed methodologies, completed reports, and other pertinent information submitted to the RWQCB and USEPA throughout the year are available online at the City's Metropolitan Wastewater Department website (http://www.sandiego.gov/mwwd).

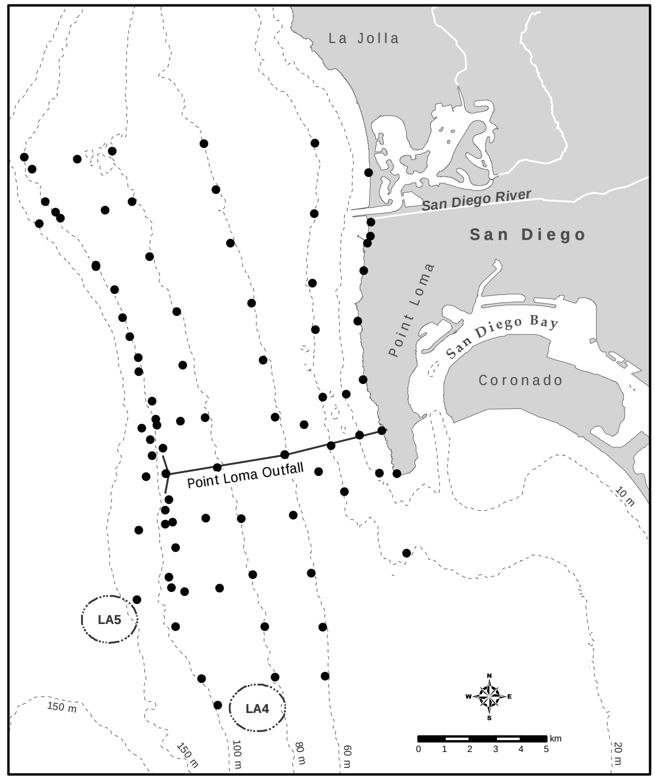

Figure 1.1
Receiving waters monitoring stations for the Point Loma Ocean Outfall Monitoring Program.

In addition to the above activities, the City participates in or supports other projects relevant to assessing ocean quality in the region. One such project is a remote sensing study of the San Diego/Tijuana coastal region that is jointly funded by the City and the International Boundary and Water Commission (IBWC). A long-term study of the Point Loma kelp forest funded by the City is also being conducted by scientists at the Scripps Institution of Oceanography (see City of San Diego 2003), while the City also participates with a number of other agencies to fund aerial surveys of all the major kelp beds from San Diego and Orange Counties (e.g., MBC 2007). Finally, the current MRP includes plans to perform adaptive or special strategic process studies as determined by the City in conjunction with the RWQCB and USEPA. Such studies have included a comprehensive scientific review of the Point Loma ocean monitoring program (see SIO 2004), a large-scale sediment mapping study of both the Point Loma and South Bay coastal regions (see Stebbins et al. 2004), and a pilot study of deep benthic habitats of the continental slope off San Diego (see Stebbins and Parnell 2005). Additionally, in 2004 the City began sampling again at the recovery stations mentioned above as part long-term annual assessment project of benthic conditions near the original outfall discharge site. In addition, a multi-phase project, the Moored Observation System Pilot Study (MOSPS), is underway to examine the dynamics and strength of the thermocline and local currents of the receiving waters off Point Loma (Storms et al. 2006). This project includes a system of moored temperature loggers (thermistor strings) and Acoustic Doppler Current Profilers (ADCPs) deployed in the vicinity of the PLOO to begin evaluating the major modes of circulation near the outfall.

This report presents the results of all regular receiving waters monitoring activities conducted as part of the Point Loma ocean monitoring program in 2007. Results of the remote sensing surveys conducted during the year (Svejkovsky 2008) are also considered and integrated into interpretations of oceanographic and water quality data. Comparisons are also made to conditions present during previous years in order to evaluate any changes that may have occurred related to the outfall or other anthropogenic or natural events. The major components of the monitoring program are covered in the following chapters: Oceanographic Conditions, Microbiology, Sediment Characteristics, Macrobenthic Communities, Demersal Fishes and Megabenthic Invertebrates, and Bioaccumulation of Contaminants in Fish Tissues. A glossary of technical terms is included.

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Chapter 2. Ocean Conditions

INTRODUCTION

The City of San Diego monitors oceanographic conditions in the region surrounding the Point Loma Ocean Outfall (PLOO) to assist in evaluating possible impacts of the outfall on the marine environment. Treated wastewater is discharged to the Pacific Ocean via the PLOO at depths of ~94–98 m and at a distance of approximately 7.2 km west of the Point Loma peninsula. During 2007, average daily flow through the outfall was 161 mgd. Changes in current patterns, water temperatures, salinity, and density can affect the fate of the wastewater plume. These types of changes can also affect the distribution of turbidity (or contaminant) plumes that originate from various point and non-point sources. In the Point Loma region these include tidal exchange from San Diego Bay and Mission Bay, outflows from the San Diego River, the Tijuana River and northern San Diego County lagoons and estuaries, storm drains or other water discharges, and surface water runoff from local watersheds. For example, flows from San Diego Bay and the Tijuana River are fed by 1,075 km^2 and 4,483 km^2 of watershed, respectively, and can contribute significantly to nearshore turbidity, sedimentation, and bacterial contamination (see Largier et al. 2004). Overall, these different factors can affect water quality conditions either individually or synergistically.

The fate of PLOO wastewater discharged into deep offshore waters at the edge of the continental shelf is determined by oceanographic conditions and other events that impact horizontal and vertical mixing. Consequently, oceanographic parameters such as water temperature, salinity, and density that determine the mixing potential of the water column are important components of ocean monitoring programs (Bowden 1975). Analysis of the spatial and temporal variability of these and other parameters (e.g., transmissivity or water clarity, dissolved oxygen, pH, and chlorophyll) may also elucidate patterns of water mass movement. Monitoring patterns of change in these parameters for the receiving waters surrounding the PLOO can help: (1) describe deviations from expected oceanographic patterns (2) assess the impact of the wastewater plume relative to other input sources, (3) determine the extent to which water mass movement or mixing affects the dispersion/dilution potential for discharged materials, and (4) demonstrate the influence of natural events such as storms or El Niño/La Niña oscillations.

Remote sensing observations from aerial and satellite imagery, and evaluation of bacterial distribution patterns may provide the best indication of the horizontal transport of discharged waters in the absence of information on deepwater currents (Pickard and Emery 1990; Svejkovsky 2006, 2007a, b; also see Chapter 3). Thus, the City of San Diego combines measurements of oceanographic parameters with assessments of indicator bacteria and remote sensing data to provide further insight into the transport potential in coastal waters surrounding the PLOO discharge site. This Chapter describes the oceanographic conditions that occurred off Point Loma during 2007, and is referred to in subsequent chapters to explain patterns of bacteriological occurrence (see Chapter 3) or other changes in the local marine environment (see Chapters 4–7).

Materials and Methods

Oceanographic measurements were collected at fixed sampling sites located in a grid pattern surrounding the PLOO (**Figure 2.1**). Thirty-six offshore stations (designated F01–F36) were sampled quarterly in January, April, July, and October, usually over a 3-day period. Three of these stations (F01–F03) are located along the 18-m depth contour, while 11 sites are located along each of the following depth contours: 60-m contour (stations F04–F14); 80-m contour (stations F15–F25); 98-m contour (stations F26–F36). Eight additional stations located in the Point Loma kelp bed are subject to the

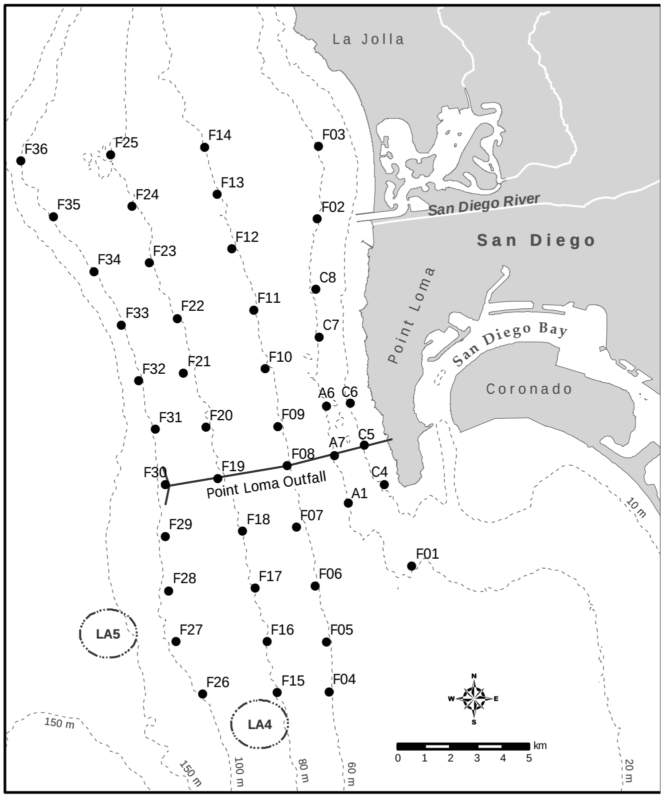

Figure 2.1
Water quality monitoring stations where CTD casts are taken, Point Loma Ocean Outfall Monitoring Program.

2001 California Ocean Plan (COP) water contact standards (SWRCB 2001). These stations include three sites (stations C4, C5, C6) located along the inshore edge of the kelp bed paralleling the 9-m depth contour, and five sites (stations A1, A6, A7, C7, C8) located along the 18-m depth contour near the offshore edge of the kelp bed. To meet 2001 COP sampling frequency requirements for kelp bed areas, sampling at the eight kelp bed stations was conducted five times per month.

Data for various water column parameters were collected using a SeaBird conductivity, temperature, and depth (CTD) instrument. The CTD was lowered through the water column at each station to collect continuous measurements of water temperature (°C), salinity (parts per thousand = ppt), density (δ/θ), pH, water clarity (% transmissivity), chlorophyll *a* (µg/L), and dissolved oxygen (mg/L). Profiles of each parameter were then constructed for each station by averaging the data values recorded over 1-m depth intervals. This ensured that physical measurements used in subsequent data analyses could correspond to discrete sampling depths for indicator bacteria (see Chapter 3). Visual observations of weather and water conditions were recorded just prior to each CTD cast.

Remote Sensing – Aerial and Satellite Imagery

Monitoring of the PLOO area and neighboring coastline also included aerial and satellite image analysis performed by Ocean Imaging (OI) of Solana Beach, CA. All usable images captured during 2007 by the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite were downloaded, and several high clarity Landsat Thematic Mapper (TM) images were purchased. High resolution aerial images were collected with OI's DMSC-MKII digital multispectral sensor (DMSC). The sensor's four channels were configured to a specific wavelength (color) combination designed to maximize detection of the PLOO discharge signature by differentiating between wastewater and coastal turbidity plumes. The depth penetration of the DMSC sensor varies between 8 and 15 m depending on overall water clarity. The spatial resolution of the data is dependent upon aircraft altitude, but is typically maintained at 2 m. Fifteen aerial surveys were flown in 2007, which consisted of two overflights per month during the winter when the outfall plume had the greatest surfacing potential (see below), and one flight per month during the spring and summer.

Data Treatment

The water column parameters measured in 2007 were summarized for each month by depth zone; profile data from the eight kelp stations were summarized for surface depths (≤2 m) and bottom depths (10–20 m), whereas profile data from the 36 offshore stations were summarized for surface depth (≤2 m), mid-depths (10–20 m), and bottom depths (≥ 88 m).

Mean temperature and salinity profile data from 2007 were compared with profile plots consisting of means ±1 standard deviation (SD) at 5 m depth increments for 1995–2007. The results from CTD casts conducted prior to 1995 were not comparable to later monitoring data due to changes in instrumentation. Data for the comparisons included herein were limited to the three stations located nearest the outfall discharge site along the 98-m depth contour. These include station F30 located immediately offshore of the center of the outfall wye, station F29 located 1.25 km south of the south diffuser, and station F31 located ~1.42 km north of the north diffuser. In addition, a time series of anomalies for each water column parameter was created to evaluate significant oceanographic events in the PLOO region. Anomalies were calculated by subtracting the monthly means for each year (1995–2007) from the mean of all 13 years combined. Means were calculated using the same three stations described above, all depths combined.

Results and Discussion

Climate Factors that Influence Oceanographic Conditions

Southern California weather can generally be classified into wet (winter) and dry (spring–fall) seasons (NOAA/NWS 2008a), and differences between these seasons affect certain oceanographic conditions (e.g., water column stratification, current patterns and direction). Understanding patterns of change in such conditions is important in that they can affect the transport and distribution of wastewater, storm water, or other types of turbidity plumes that may arise from various point or non-point sources (e.g., ocean outfalls, storm drains, outflows from rivers and bays, surface runoff from coastal watersheds). Winter conditions typically prevail in southern California from December through February during which time higher wind, rain and wave activity often contribute to the formation of a well-mixed or relatively homogenous (non-stratified) water column. The chance that the wastewater plume from the PLOO may surface is highest during such times when there is little, if any, stratification of the water column. These conditions often extend into March as the frequency of winter storms decreases and the seasons begin to transition from wet to dry. In late March or April the increasing elevation of the sun and lengthening days begin to warm surface waters, mixing conditions diminish with decreasing storm activity, and seasonal thermoclines and pycnoclines become re-established. Once the water column becomes stratified again by late spring, minimal mixing conditions typically remain throughout the summer and early fall months. In October or November, cooler temperatures associated with seasonal changes in isotherms, reduced solar input, along with increases in stormy weather, begin to cause the return of well-mixed or non-stratified water column conditions.

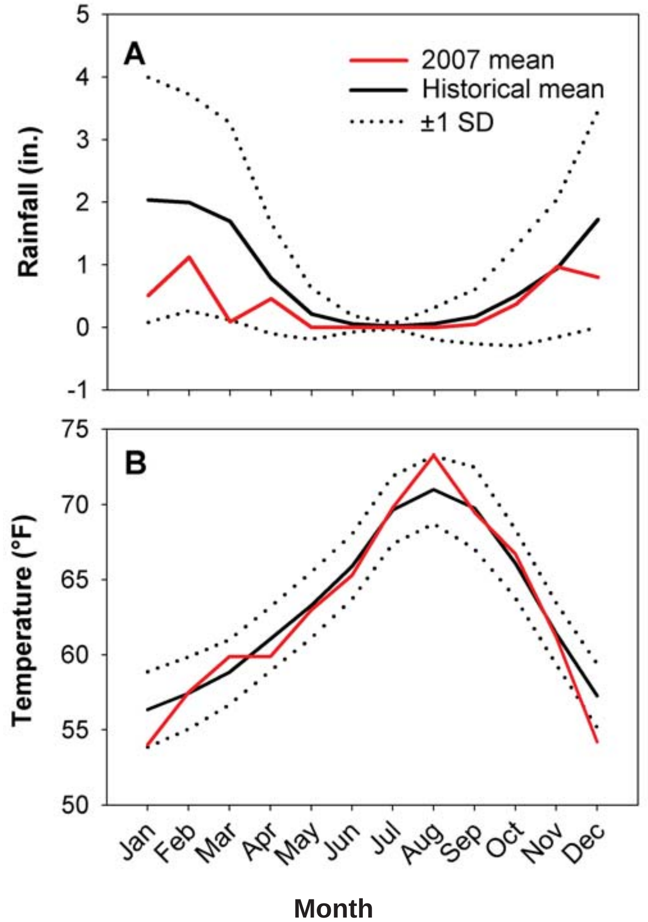

Figure 2.2
Total monthly rainfall (A) and monthly mean air temperature (B) at Lindbergh Field (San Diego, CA) for 2007 compared to monthly mean rainfall and air temperature (± one standard deviation) for the historical period 1914–2006.

Total rainfall was a little over 4 inches in the San Diego region during 2007, which was well below the historical average of more than 10 inches/year (NOAA/NWS 2008b). Although annual rainfall was less than normal for the year, the greatest and most frequent rains occurred during February similar to expected seasonal patterns (**Figure 2.2A**). In contrast, air temperatures were generally similar during the year to historical averages, although

Table 2.1

Summary of temperature (=temp; °C), salinity (ppt), density (δ/θ), dissolved oxygen (DO; mg/L), pH, chlorophyll *a* (Chl; µg/L), and transmissivity (XMS; %) for surface (≤2 m) and bottom (10-20 m) waters at all Point Loma kelp stations during 2007. Values are expressed as means for all stations combined.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp	*Surface*	14.7	14.7	14.4	15.3	16.3	17.8	20.0	22.4	18.3	17.8	15.3	14.4
	Bottom	14.4	13.9	12.3	12.0	12.0	12.7	14.7	15.1	13.6	13.8	13.2	13.9
Density	*Surface*	24.95	24.92	25.05	24.91	24.71	24.40	23.81	23.21	24.14	24.23	24.75	24.92
	Bottom	25.00	25.10	25.54	25.64	25.65	25.52	25.02	24.91	25.16	25.10	25.17	25.02
Salinity	*Surface*	33.58	33.55	33.63	33.70	33.75	33.81	33.77	33.82	33.65	33.59	33.51	33.47
	Bottom	33.58	33.57	33.73	33.79	33.82	33.80	33.72	33.68	33.60	33.54	33.49	33.47
DO	*Surface*	7.9	7.8	8.4	8.5	9.4	9.4	8.3	8.1	8.3	8.0	7.8	7.8
	Bottom	7.6	6.9	5.8	5.0	5.0	5.6	7.6	7.6	7.4	7.1	6.7	7.2
pH	*Surface*	8.2	8.2	8.2	8.2	8.4	8.4	8.2	8.2	8.2	8.2	8.1	8.1
	Bottom	8.1	8.1	8.0	7.9	8.0	8.0	8.1	8.1	8.1	8.1	8.0	8.0
XMS	*Surface*	84	76	78	75	77	73	78	81	82	82	80	82
	Bottom	85	79	82	85	85	82	83	85	85	85	84	83
Chl	*Surface*	2.2	2.0	4.0	8.4	10.4	15.8	3.4	3.0	2.8	2.2	4.2	3.1
	Bottom	3.0	2.8	6.8	3.8	5.6	12.9	6.1	5.0	4.8	3.1	3.6	3.3

exceptions occurred in January, August and December (**Figure 2.2B**). The above normal air temperatures during the summer coincided with higher than normal surface water temperatures and salinity values for the PLOO region (see below). Aerial imagery indicated that current flow was predominantly southward in 2007, although with occasional northward flows occurred following storm events (Svejkovsky 2008). For example, increased outflows from the Tijuana River near Imperial Beach and Los Buenos Creek in northern Baja California during the wet season resulted in large northward-flowing turbidity plumes in San Diego coastal waters.

Oceanographic Conditions in 2007

Water Temperature

Water temperature is the main factor affecting water density and stratification of southern California ocean waters (Dailey et al. 1993, Largier et al. 2004), and differences in surface and bottom temperatures can provide the best indication of the surfacing potential of wastewater plumes. Thermal stratification at the Point Loma kelp stations generally followed normal seasonal patterns in 2007 with the least stratification occurring during the winter months of January, February and December, and the greatest stratification in August (**Figure 2.3**). Surface temperatures at the kelp stations ranged from 14.4°C in March and December to 22.4°C in August , whereas bottom temperatures ranged from 12.0°C in April and May to 15.1°C in August (**Table 2.1**). Thermal stratification also appeared to follow typical seasonal patterns at the quarterly offshore sites (see **Figure 2.4**), with the water column ranging from slightly stratified in January to strongly stratified in July. Overall, offshore surface temperatures ranged from 14.7 to 20.9°C during the year, while bottom temperatures ranged from 9.9 to 11.4°C (**Table 2.2**). Since temperature is the main contributor to water column stratification

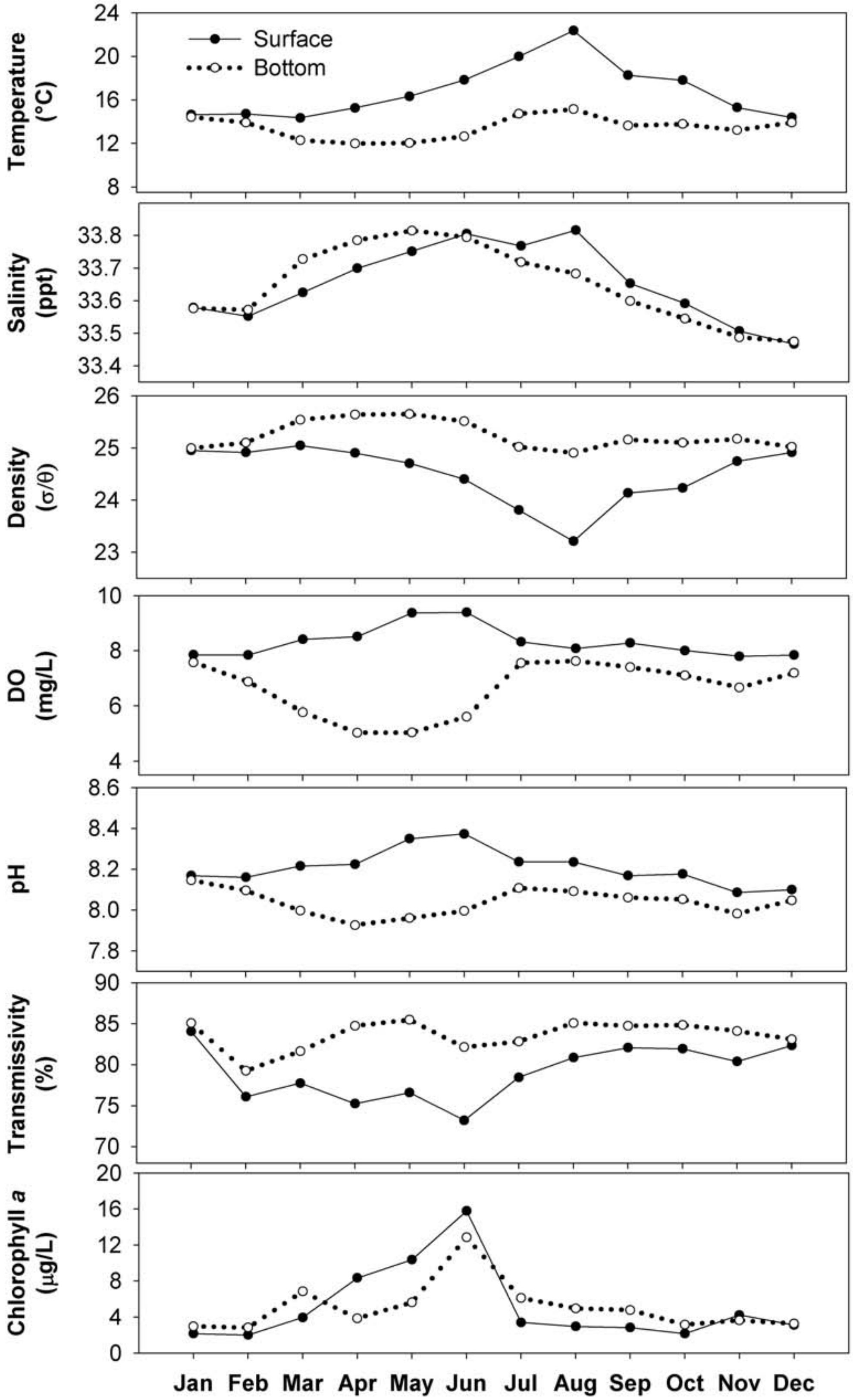

Figure 2.3
Monthly mean temperature, density, salinity, transmissivity, dissolved oxygen (DO), pH, and chlorophyll *a* values for surface (≤2m) and bottom (10-20 m) waters at the Point Loma kelp stations during 2007.

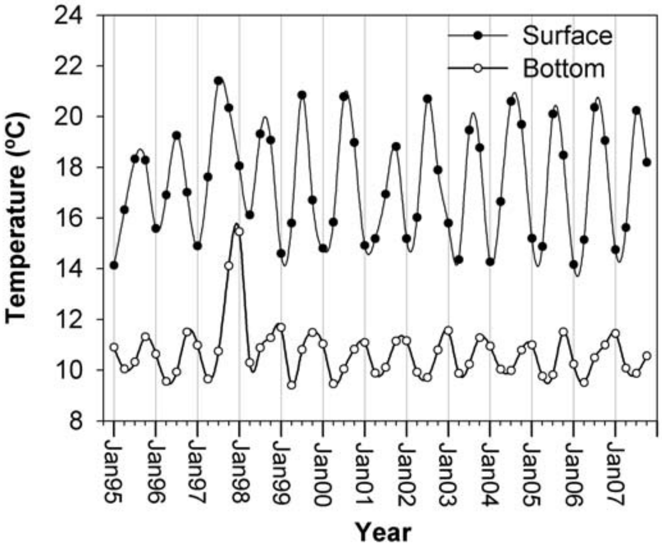

Figure 2.4
Mean surface and bottom water temperatures for PLOO offshore stations from 1995–2007.

in southern California, these differences between surface and bottom waters along with seasonal thermoclines were important to limiting the surfacing potential of the waste field throughout the year (see Chapter 3). Moreover, the wastewater plume was not detectable in aerial imagery during 2007 (Svejkovsky 2008).

Salinity
Salinities at the kelp stations ranged from 33.47 ppt in December to 33.82 ppt in August surface waters, and from 33.47 ppt in December to 33.82 ppt in May at bottom depths (Table 2.1). Salinity at these stations followed normal seasonal patterns; salinities increased at all depths from March through May, peaked in August at the surface, and then declined at both the surface and bottom (Figure 2.3). Surface salinities at the offshore stations ranged from 33.56 ppt in January to 33.76 ppt in July, while bottom salinities ranged from 33.73 in January to 33.99 in April (Table 2.2). Although data for the offshore stations are limited to only four times a year, salinities at these stations appeared to follow seasonal patterns similar to those that occurred at the kelp stations (i.e., peaked in summer, declined in the fall).

Density
Seawater density, a product of temperature, salinity, and pressure, is influenced primarily by temperature in coastal shelf waters where salinity profiles are relatively uniform (i.e., change little with depth). Therefore, changes in density typically mirror changes in temperature. This relationship was true for 2007 data, as indicated by water column data collected at the kelp and offshore stations (Tables 2.1, 2.2). The differences between surface and bottom water densities at the kelp stations resulted in a pycnocline from April through October with maximum stratification occurring in August (Figure 2.3). Similar patters were present at the offshore stations with the highest densities occurring where water temperatures were coldest. Surface seawater densities decreased between January, April and July, but were higher again in October. Bottom seawater densities increased between April and July and then decreased in October.

Dissolved Oxygen, pH and Transmissivity
Average dissolved oxygen (DO), pH and transmissivity values for 2007 are summarized in Tables 2.1 and 2.2. DO concentrations averaged 7.8 to 9.4 mg/L in surface waters and 5.0 to 7.6 mg/L in bottom waters for the kelp stations, while mean values for the quarterly offshore stations ranged between 7.8–8.4 mg/L at the surface and 2.9–4.4 mg/L near the bottom. Mean pH values ranged from 8.1 to 8.4 in surface waters and 7.9 to 8.1 in bottom waters at the kelp stations, and between 7.7 and 8.2 across all depths for the offshore stations. Transmissivity averaged 73–85% at the kelp stations and 81–90% for the offshore stations.

Chlorophyll a
Mean chlorophyll *a* concentrations in surface waters ranged from 2.0 μg/L in February to 15.8 μg/L in June at the kelp stations, and from 1.0 μg/L in October to 4.2 μg/L in April at the offshore stations (Tables 2.1 and 2.2). The high chlorophyll values reported for surface waters at the kelp stations beginning in March corresponded to phytoplankton blooms observed in MODIS satellite imagery (Svejkovsky 2008). Such spring blooms are likely the result of upwelling events that typically occur during this time of the year (Jackson 1986, Svejkovsky 2008). These blooms developed into a red tide surrounding the kelp

Table 2.2

Summary of temperature (=temp; °C), salinity (ppt), density (δ/θ), dissolved oxygen (DO; mg/L), pH, chlorophyll *a* (Chl; μg/L), and transmissivity (XMS; %) for surface (≤2 m), mid-depth (10-20 m) and bottom (≥88 m) waters at all PLOO offshore stations during 2007. Values are expressed as means for all stations combined.

		Jan	Apr	Jul	Oct
Temp	*Surface*	14.7	15.6	20.2	18.2
	Mid	14.6	13.2	15.2	15.4
	Bottom	11.4	10.1	9.9	10.6
Density	*Surface*	24.92	24.81	23.75	24.21
	Mid	24.95	25.32	24.89	24.71
	Bottom	25.71	26.15	26.13	25.91
Salinity	*Surface*	33.56	33.66	33.76	33.67
	Mid	33.56	33.67	33.67	33.50
	Bottom	33.73	33.99	33.92	33.78
DO	*Surface*	7.8	8.4	8.0	7.8
	Mid	7.7	7.1	9.1	8.1
	Bottom	3.8	2.9	3.6	4.4
pH	*Surface*	8.1	8.2	8.2	8.1
	Mid	8.1	8.1	8.2	8.1
	Bottom	7.8	7.7	7.7	7.8
XMS	*Surface*	85	81	86	87
	Mid	86	84	86	88
	Bottom	89	88	90	89
Chl	*Surface*	4.0	4.2	1.5	1.0
	Mid	4.8	6.1	3.6	2.9
	Bottom	0.2	0.3	0.5	0.4

stations during June and then declined thereafter. During March and from July through October, chlorophyll levels were higher at bottom depths at the kelp stations, which most likely reflected decaying phytoplankton sinking towards the bottom. Increases in dissolved oxygen levels and pH along with declines in water clarity (transmissivity) that occurred at the kelp stations in 2007 were likely influenced by increases in phytoplankton densities based on chlorophyll measurements (Figure 2.3). Chlorophyll concentrations were much lower at the offshore stations (Table 2.2).

Historical Assessment of Oceanographic Conditions

Profiles of mean temperature and salinity data for outfall stations F29, F30 and F31 during January and April of 2007 were similar to the historical profiles for 1995–2006 (**Figure 2.5**). Temperature and salinity were relatively high during July when values in the top 40 m approached the upper end of the historical range (i.e., means ± 1 SD). These higher values were most likely influenced by increased summer air temperatures (see Figure 2.2B). Low water temperatures and high salinities in October 2007, especially at depths below 40 m, are likely indicative of upwelling (see Figure 2.5). Salinity also decreased sharply at this time at depths between about 15 and 40 m depths, which most likely represents a mixture of less dense seawater and freshwater effluent discharge via the outfall that was pushed upward by the intrusion of denser upwelled seawater. The upward movement of wastewater creates a doming effect at these stations near the outfall that has also been observed in multispectral satellite imagery (see Svejkovsky 2008). However, remote sensing observations never revealed the plume reaching surface waters in 2007 (Svejkovsky 2008). The restriction of elevated densities of indicator bacteria to depths ≥60 m also indicates that the wastewater plume remained trapped in relatively deep waters during the year (see Chapter 3).

A review of historical oceanographic data between 1995 and 2007, using the same three PLOO stations (F29, F30, and F31), does not reveal any measurable impact that can be attributed to discharge (**Figure 2.6**). Although the change from monthly to quarterly sampling after July 2004 has decreased the number of data points for interpretation, the results are still notably consistent with the changes in large-scale patterns in the region as observed by CalCOFI (Peterson et al. 2006; Goericke et al. 2007). These authors describe four significant events that have affected the California Current System (CCS) during the last decade: (1) the 1997–1998 El Niño; (2) a dramatic shift to cold ocean conditions that lasted from 1999 through 2002; (3) a more subtle but persistent return to warm ocean conditions beginning

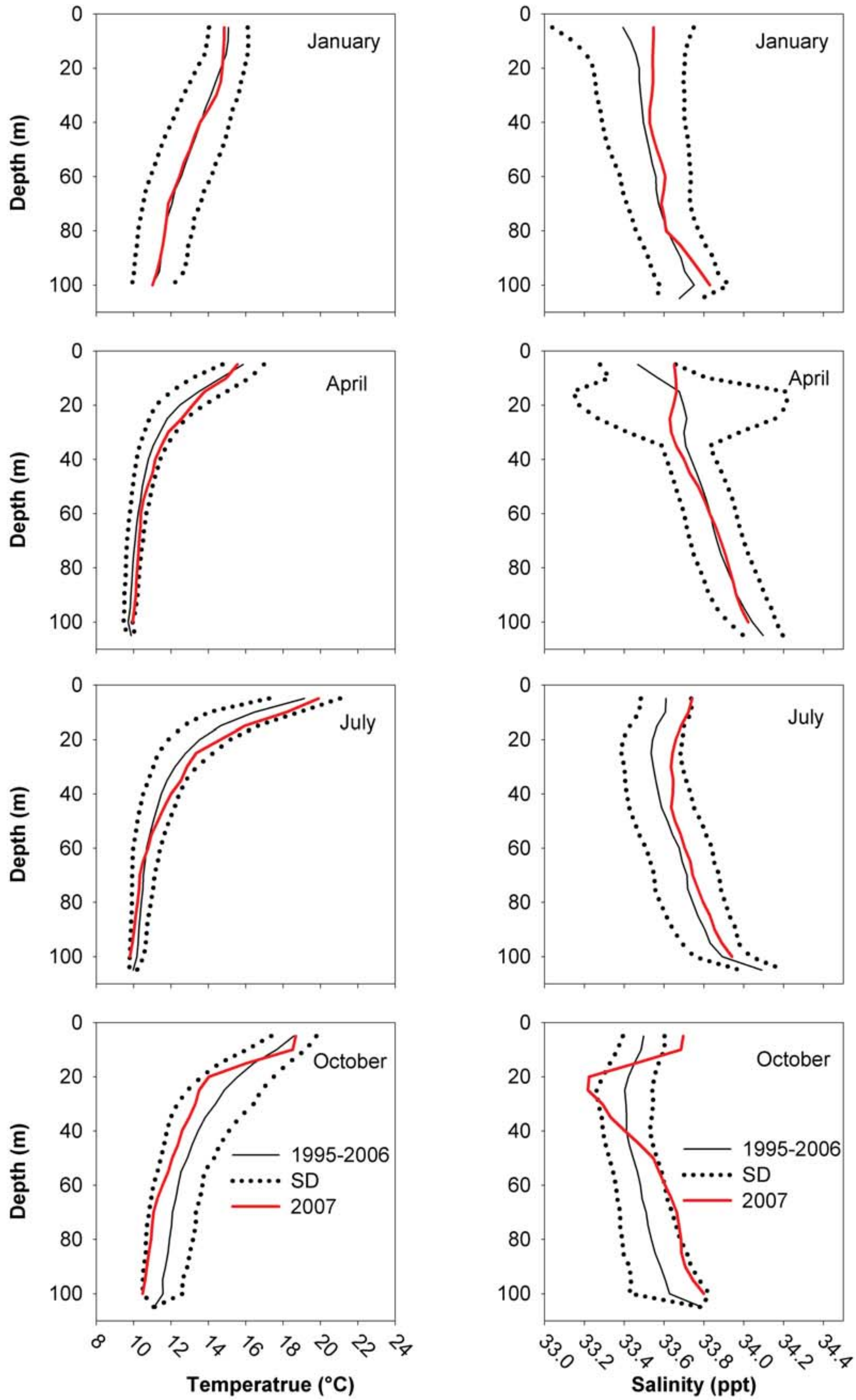

Figure 2.5

Comparison of temperature and salinity water column profiles for 2007 compared to historical data for 1995-2006 at select offshore stations located nearest the PLOO discharge site (F29, F30, and F31; see Figure 2.1). The historical data represent 12-year means ±1 standard deviation (SD) for each quarterly survey month.

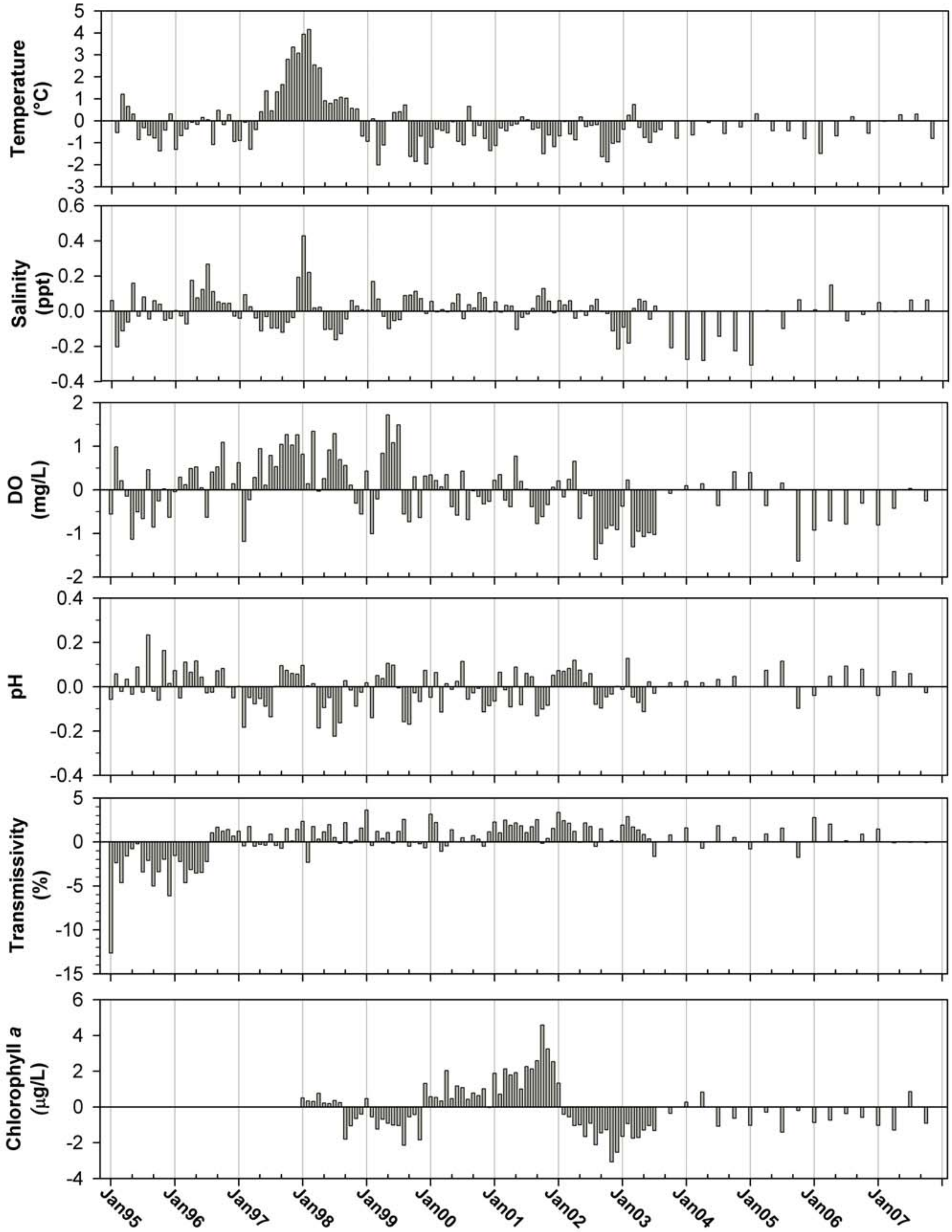

Figure 2.6

Time series of temperature, salinity, transmissivity, pH, dissolved oxygen (DO), and chlorophyll anomalies between 1995 and 2007. Anomalies were calculated by subtracting the monthly means for each year (1995–2007) from the mean of all 13 years combined; data were limited to stations F29, F30, and F31, all depths combined.

in October 2002; (4) the intrusion of subarctic surface waters that resulted in lower than normal salinities in southern California during 2002–2003 (Goericke et al. 2007). Temperature and salinity data for the Point Loma region are consistent with the first, second, and fourth CCS events.

Overall water clarity (transmissivity) around the outfall has tended to be higher than the historical mean since mid-1996. The lower transmissivity values in 1995 and 1996 may have been related to sediment plumes associated with the offshore disposal of dredged materials from a large dredging project in San Diego Bay. Decreases in transmissivity during winter periods such as in 1998 and 2000 appear to be the result of increased amounts of suspended sediments caused by strong storm activity (see NOAA/NWS 2008b). In addition, small decreases during the late spring and early summer were probably related to phytoplankton blooms such as those observed throughout the region in 2005 (see City of San Diego 2006). Anomalies in transmissivity values during 2006 and 2007 were mostly indicative of reduced turbidity due to the relatively low rainfall that occurred during these two years.

Chlorophyll *a* concentrations in the Point Loma region have been below average most of the time in recent years (Figure 2.6). These results are more consistent with those observed in northern Baja California, and are in contrast to the rest of southern California during recent years (Peterson et al. 2006). Occasional periods of higher than normal chlorophyll concentrations within the Point Loma region occurred as a result of red tides caused by the dinoflagellate *Lingulodinium polyedra*. This species persists in river mouths and responds with rapid population increases to optimal environmental conditions, such as significant amounts of nutrients from river runoff during rainy seasons (Gregorio and Pieper 2000). During 2007, chlorophyll levels were generally below historical mean values, with the exception of a positive spike in July that corresponded to the remnant of a phytoplankton bloom that peaked in June (see above).

There were no apparent trends in pH values or dissolved oxygen concentrations related to the PLOO. These parameters are complex, dependent on temperature and depth, and sensitive to physicochemical and biological processes (Skirrow 1975). Moreover, dissolved oxygen and pH are subject to diurnal and seasonal variations that make temporal changes difficult to evaluate. However, below normal concentrations for dissolved oxygen during 2005–2007 appear to be related to the low levels of chlorophyll *a* levels during these years.

Summary and Conclusions

There was no apparent relationship between the outfall and values of ocean temperature, salinity, pH, transmissivity, chlorophyll *a*, and dissolved oxygen during 2007. Instead, oceanographic conditions generally followed normal seasonal patterns. For example, differences between surface and bottom waters (i.e., stratification) first developed in spring, peaked in the summer and then declined thereafter. Since temperature is the main contributor to water column stratification in southern California, these differences between surface and bottom waters along with seasonal thermoclines were important to the prevention of the waste field surfacing throughout the year (see Chapter 3). The restriction of elevated densities of indicator bacteria to depths ≥60 m also indicates that the wastewater plume remained trapped in relatively deep waters during the year (see Chapter 3). Moreover, the wastewater plume was not detectable in aerial imagery during 2007 (Svejkovsky 2008).

Long-term analysis of water column data collected between 1995 and 2007 also did not reveal any changes in oceanographic parameters at stations around the PLOO that could be attributed to the discharge of wastewater. Instead, major changes in water temperatures and salinity for the Point Loma region corresponded to significant climate events that occurred within the California Current System between 1995 and 2005 (see previous discussion). During late 2006 and early 2007, no clear patterns were observed in the California Current System, and regional or local processes dominated observed patterns. Additionally, water clarity has increased in the PLOO region over the past several years, and changes in pH and dissolved oxygen levels have not exhibited any apparent trends related to wastewater discharge.

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Chapter 3. Microbiology

INTRODUCTION

The City of San Diego performs water quality monitoring along the shoreline and in offshore ocean waters for the region surrounding the Point Loma Ocean Outfall (PLOO). This aspect of the City's ocean monitoring program is designed to assess general oceanographic conditions, evaluate patterns in movement and dispersal of the PLOO wastewater plume, and monitor compliance with water contact standards defined in the 2001 California Ocean Plan (COP) as according to NPDES permit specifications (see Chapter 1). Results of all sampling and analyses, including COP compliance summaries, are submitted to the San Diego Regional Water Quality Control Board in the form of monthly receiving waters monitoring reports. Densities of indicator bacteria (total coliforms, fecal coliforms, enterococcus), along with oceanographic data (see Chapter 2), are evaluated to provide information about the movement and dispersion of wastewater discharged to the Pacific Ocean through the outfall. Analyses of these data may also help identify other point or non-point sources of bacterial contamination in the region (e.g., outflows from rivers or bays, surface runoff from local watersheds). This chapter summarizes and interprets patterns in seawater bacterial concentrations collected for the Point Loma region during 2007.

Materials and Methods

Field Sampling

Seawater samples for bacteriological analyses were collected at a total of 52 NPDES-mandated shore, kelp bed or offshore monitoring sites during 2007 (**Figure 3.1**). Sampling was performed weekly at eight monitoring sites located along the shore (i.e., stations D4, D5, and D7–D12) to monitor bacterial levels along public beaches and evaluate compliance with the 2001 COP water contact standards (see **Box 3.1**). Eight stations located in nearshore waters within the Point Loma kelp forest were also monitored to assess water quality conditions in areas used for recreational activities such as SCUBA diving, surfing, fishing and kayaking. These include stations C4, C5 and C6 located near the inner edge of the kelp bed along the 9-m depth contour, and stations A1, A6, A7, C7 and C8 located near the outer edge of the kelp bed along the 18-m depth contour. The kelp stations are also subject to COP water contact standards, and were therefore sampled weekly, such that each day of the week was represented over a two month period. Thirty-six offshore stations (F01–F36) were sampled quarterly during January, April, July and October in order to estimate the spatial extent of the wastewater plume at these times. Complete sampling of all 36 stations usually occurs over a 3 day period. Three of these offshore sites (stations F01–F03) are located along the 18-m depth contour, while 33 sites

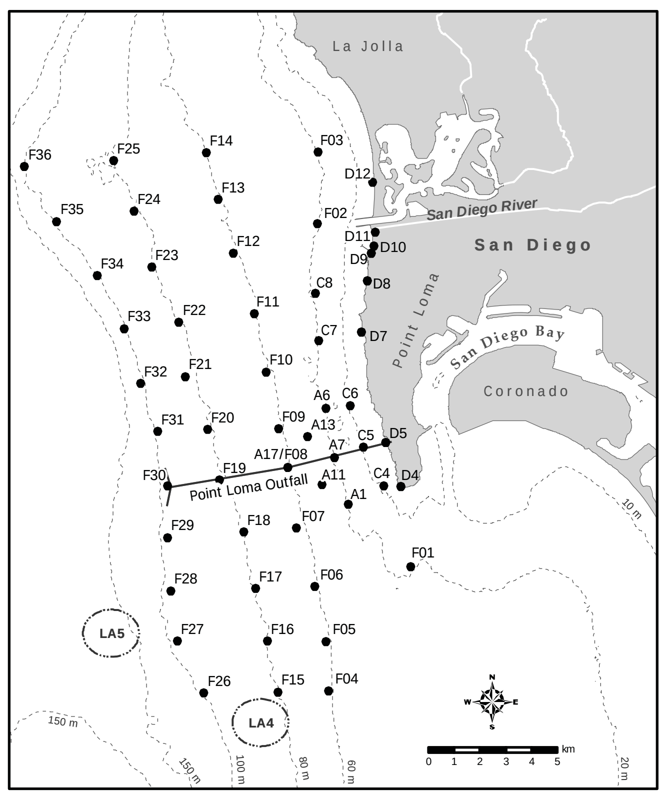

Figure 3.1
Water quality monitoring stations for the Point Loma Ocean Outfall Monitoring Program.

Box 3.1

Bacteriological compliance standards for water contact areas, 2001 California Ocean Plan (SWRCB 2001). CFU = colony forming units.

(1) *30-day total coliform standard* — no more than 20% of the samples at a given station in any 30-day period may exceed a concentration of 1000 CFU per 100 mL.

(2) *10,000 total coliform standard* — no single sample, when verified by a repeat sample collected within 48 hrs, may exceed a concentration of 10,000 CFU per 100 mL.

(3) *60-day fecal coliform standard* — no more than 10% of the samples at a given station in any 60-day period may exceed a concentration of 400 CFU per 100 mL.

(4) *geometric mean* — the geometric mean of the fecal coliform concentration at any given station in any 30-day period may not exceed 200 CFU per 100 mL, based on no fewer than 5 samples.

(11 per transect) are distributed along the 60-m (stations F04–F14), 80-m (stations F15–F25) and 98-m (stations F26–F36) depth contours. In addition, three sites (stations A11, A13, A17) located seaward of the kelp bed were sampled as part of the weekly kelp bed sampling array to ensure that water quality is appropriately documented in the area of the original Point Loma discharge location. Analyses for these additional special study stations are not included herein, but have been reported previously (see City of San Diego 2007b, 2008a).

Seawater samples for the eight shore stations were collected from the surf zone and stored in sterile 250-mL bottles. In addition, visual observations of water color and clarity, surf height, human or animal activity, and weather conditions were recorded at the time of sample collection. The samples were then transported on blue ice to the City of San Diego's Marine Microbiology Laboratory (CSDMML) and analyzed to determine concentrations of total coliform, fecal coliform, and enterococcus bacteria. Seawater samples from the kelp bed and quarterly offshore stations were collected using either a series of Van Dorn bottles or a rosette sampler fitted with Niskin bottles. These samples were collected at 3-5 discrete depths per site dependent upon station depth (see **Table 3.1**). Aliquots for each analysis were drawn into appropriate sample containers. All seawater samples were refrigerated on board ship and then transported to the CSDMML for analysis of the above indicator bacteria (total and fecal coliforms, enterococcus). Visual observations of weather conditions, sea state, and human or animal activity in the area were also recorded at the time of sampling. Monitoring of the PLOO area and neighboring coastline also included aerial and satellite image analysis performed by Ocean Imaging of Solana Beach, California (Svejkovsky 2008; also see Chapter 2).

Laboratory Analyses and Data Treatment

All bacterial analyses were performed within 8 hours of sample collection and conformed to the standard membrane filtration techniques (see APHA 1992). The CSDMML follows guidelines issued by the EPA Water Quality Office, Water Hygiene Division, and the California State Department of Health Services (CDHS) Environmental Laboratory Accreditation Program (ELAP) with respect to sampling and analytical procedures (Bordner et al. 1978, APHA 1992).

Colony counting of indicator bacteria, calculation of results, data verification and reporting all follow guidelines established by the EPA (Bordner et al. 1978). According to these guidelines, plates with bacterial counts above or below the ideal counting range were given greater than (>), less

Table 3.1
Depths at which bacteriological samples are collected at the PLOO kelp and quarterly offshore stations.

	Sample depth (m)								
Station transect	**1**	**3**	**9**	**12**	**18**	**25**	**60**	**80**	**98**
9-m Kelp bed	x	x	x						
18-m Kelp bed	x			x	x				
18-m Offshore	x			x	x				
60-m Offshore	x					x	x		
80-m Offshore	x					x	x	x	
98-m Offshore	x					x	x	x	x

than (<), or estimated (e) qualifiers. However, these qualifiers were dropped and the counts treated as discrete values during calculation of mean values and in determining compliance with COP standards.

Bacteriological benchmarks defined in the 2001 COP or Assembly Bill 411 (AB 411) were used as reference points to distinguish elevated bacteriological values in receiving water samples discussed in this report. These benchmarks are: (a) >1000 CFU/100 mL for total coliforms; (b) >400 CFU/100 mL for fecal coliforms; (c) >104 CFU/100 mL for enterococcus. Furthermore, any seawater sample with a total coliform concentration ≥1000 CFU/100 mL and a fecal:total (F:T) ratio ≥0.1 is considered representative of contaminated waters (see CDHS 2000). Samples that met these latter two criteria were used as indicators of the PLOO waste field or other sources of bacterial contamination.

Quality assurance tests were performed routinely on seawater samples to ensure that sampling variability did not exceed acceptable limits. Duplicate and split bacteriological samples were collected and processed according to method requirements to measure intra-sample and inter-analyst variability, respectively. Results of these procedures were reported in the laboratory's Quality Assurance Report for 2007 (City of San Diego 2008b).

Maps of total coliform densities at the offshore stations were generated using the Spatial Analyst extension for ArcGIS 9.1 in order to estimate possible distribution of the PLOO waste field during the quarterly sampling months. The Inverse Distance Weighting algorithm was used with the power set to 3, a neighborhood of 5, and default values for all other parameters. Coliform densities from samples collected at depths shallower than 60 m were not used because contaminated water was detected in only four such samples during the year. The interpolations of coliform distribution patterns in these relatively deep waters are meant for simplified data visualization purposes only and are not statistically significant.

Results and Discussion

Shore Stations

Concentrations of indicator bacteria were generally very low along the shoreline in 2007, which likely reflects the relatively low rainfall that occurred during the year (see **Table 3.2**). Monthly densities at the different shore stations averaged 24–622 CFU/100 mL for total coliforms, 4–224 CFU/100 mL for fecal coliforms, and 4–215 CFU/100 mL for enterococcus. Five of the nine shoreline samples that had total coliform concentrations ≥1,000 CFU/100 mL during the year were collected within 72 hours after a rain event (see **Table 3.3**). These included samples collected at stations D9, D10 or D11 during February, April or December. Three of the five samples also had F:T ratios ≥0.1 and were therefore indicative of contaminated waters (i.e., samples from D11 in February, and from D10 and D11 in December). In contrast, the other four samples with elevated total coliforms occurred during periods of no rain. These included samples collected at stations D4 and D11 in June, station D7 in July, and station D8

Table 3.2

Summary of rainfall and indicator bacteria levels at PLOO shore stations during 2007. Rainfall data are from Lindbergh Field, San Diego, CA. Total coliform (Total), fecal coliform (Fecal), and enterococcus (Entero) densities are expressed as mean CFU/100 mL per month. Stations are listed from south to north.

Month	Rain (in)		D4	D5	D7	D8	D9	D10	D11	D12	All stations
Jan	0.51	*Total*	29	21	14	204	4	18	21	19	41
		Fecal	3	3	2	26	3	14	10	8	9
		Entero	5	14	4	26	2	5	6	20	10
Feb	1.12	*Total*	5	3	3	102	27	224	393	22	98
		Fecal	2	2	2	8	4	58	50	11	17
		Entero	3	2	2	29	5	52	38	17	18
Mar	0.09	*Total*	2	5	5	101	5	18	50	8	24
		Fecal	2	2	3	7	2	3	9	3	4
		Entero	2	2	2	7	2	21	5	4	6
Apr	0.46	*Total*	6	13	4	28	253	51	222	15	74
		Fecal	4	2	3	9	3	14	24	6	8
		Entero	2	2	3	8	4	7	10	137	22
May	0.00	*Total*	10	11	49	21	16	64	36	2	26
		Fecal	4	2	2	3	2	6	21	6	6
		Entero	2	2	2	3	4	6	9	4	4
Jun	0.00	*Total*	1085	18	132	76	20	100	256	56	218
		Fecal	42	6	2	34	2	62	207	4	45
		Entero	2	12	3	2	2	12	1686	2	215
Jul	0.00	*Total*	20	56	696	20	64	88	78	16	130
		Fecal	7	2	283	3	6	30	13	2	43
		Entero	2	2	3	2	4	10	25	3	7
Aug	0.00	*Total*	132	92	128	132	132	64	36	90	101
		Fecal	3	2	5	14	3	13	22	2	8
		Entero	2	2	3	4	4	8	5	4	4
Sep	0.05	*Total*	50	70	47	47	25	38	36	31	43
		Fecal	3	2	5	7	3	16	9	10	7
		Entero	2	3	10	3	2	10	18	44	12
Oct	0.37	*Total*	16	92	128	604	49	58	26	16	124
		Fecal	3	8	10	185	2	12	4	4	29
		Entero	10	7	7	99	3	6	6	7	18
Nov	0.97	*Total*	13	28	52	164	17	21	13	40	43
		Fecal	3	11	9	64	4	11	7	20	16
		Entero	3	7	12	25	4	11	9	14	11
Dec	0.80	*Total*	39	25	20	132	71	2311	2331	45	622
		Fecal	2	2	10	38	11	811	894	20	224
		Entero	5	5	4	30	19	520	493	35	139
		n	64	64	62	62	62	62	62	61	
Annual means		**Total**	24	24	55	128	25	112	251	34	
		Fecal	3	5	12	48	5	21	24	8	
		Entero	3	6	6	46	5	13	27	11	

Table 3.3

Summary of samples with elevated total coliform (Total), fecal coliform (Fecal), and enterococcus (Entero) densities (CFU/100 mL) at PLOO shore stations in 2007. F:T = fecal total coliform ratio. Rainfall was measured at Lindbergh Field, San Diego, CA.

Date	72-Hour rain (in.)	Station	Total	Fecal	Entero	F:T
February 22	0.14	D11	1800	200	120	0.11
April 24	0.08	D11	1000	60	4	0.06
April 24	0.08	D9	1200	2	2	0.00
June 17	0.00	D4	5400	200	2	0.04
June 23	0.00	D11	1100	960	8400	0.87
July 29	0.00	D7	3200	1400	8	0.44
October 8	0.00	D8	1600	2	2	0.00
December 1	0.94	D10	>16,000	5600	3600	0.35
December 1	0.94	D11	>16,000	6200	3400	0.39

in October; the samples from D7 and D11 also had F:T values ≥0.1. MODIS satellite imaging of the region on June 16, 17, 18, and 23 showed turbidity plumes from the San Diego River and San Diego Bay encompassing several of the shore stations (see Svejkovsky 2008), which may account for the elevated bacteria concentrations at stations D4 and D11. Furthermore, station D11 is located near the mouth of the San Diego River at a designated dog recreational area (Dog Beach). Contamination from both of these sources is a likely cause of the elevated bacterial counts at this shore station. A possible source of contamination at station D8 is a tidally influenced storm drain in the area (see Martin and Gruber 2005; City of San Diego 2007). Other sources that may have contributed to bacterial contamination along the shore include beach wrack (e.g., kelp and seagrass) and shorebirds, all of which were present during the collection of many seawater samples (City of San Diego 2007b, 2008a).

Kelp Stations

Concentrations of indicator bacteria were also very low at PLOO kelp stations in 2007. Densities at these sites during the year ranged from <2 to 3600 CFU/100 mL for total coliforms, <2 to 520 CFU/100 mL for fecal coliforms, and <2 to 110 CFU/100 mL for enterococcus (City of San Diego 2007b, 2008a). Of the 1,440 seawater samples taken from kelp stations, only four samples (<1%) had elevated total coliform levels >1000 CFU/100 mL, of which only two were indicative of contaminated seawater with F:T ratios ≥0.1 (**Table 3.4**). All four of the above samples were collected during a 72-hour rain event. No samples collected at the kelp stations had elevated fecal coliform or enterococcus values during the year.

Offshore Stations

A summary of bacterial densities collected at the PLOO offshore stations during 2007 is presented in **Figure 3.2**. Seawater samples collected from

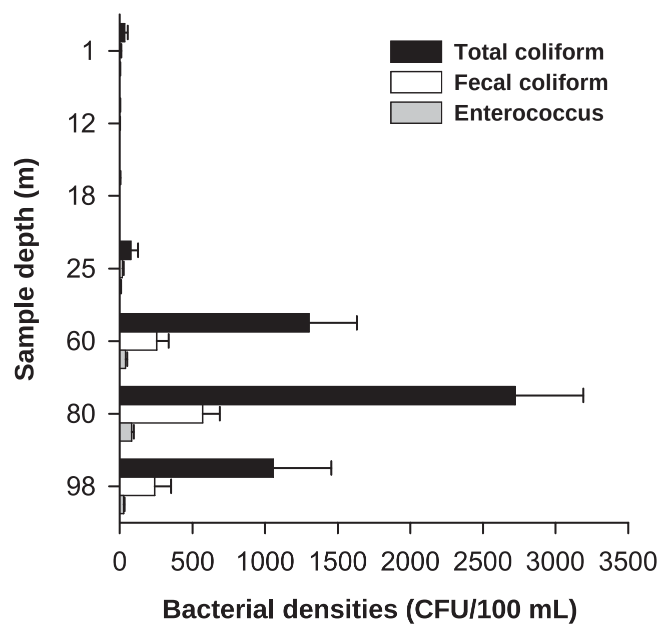

Figure 3.2

Summary of bacterial densities at PLOO offshore stations sampled in 2007. Values are expressed as means ± one standard deviation.

Table 3.4

Summary of samples with elevated total coliform (Total), fecal coliform (Fecal), and enterococcus (Entero) densities (CFU/100 mL) at PLOO kelp stations in 2007. F:T = fecal to total coliform ratio. Rainfall was measured at Lindbergh Field, San Diego, CA.

Date	72-Hour rain (in.)	Station	Depth (m)	Total	Fecal	Entero	F:T
March 1	0.15	A1	12	1400	280	34	0.20
March 1	0.15	A1	18	3600	400	78	0.11
March 1	0.15	A6	18	3600	280	88	0.08
March 1	0.15	A7	12	2000	44	100	0.02

shallow depths (i.e., along the 18-m depth contour) at the offshore stations had total coliform, fecal coliform, and enterococcus concentrations averaging less than 6 CFU/100 mL during 2007 (**Table 3.5**). In contrast, average densities of indicator bacteria from deeper waters were as high as 1831 CFU/100 mL for total coliforms (i.e., at 80 m during April). The highest average fecal coliforms (413 CFU/100 mL) also occurred in samples collected at a depth of 80 m, but during the month of January, while the highest mean enterococcus values (56 CFU/100 mL) occurred at depths of 80 and 98 m during January. Of the 564 samples collected, only 64 (~11%) may be considered indicative of contaminated waters with elevated total coliforms and an F:T ratio ≥0.1 (see **Appendix A.1**). Only four of these samples were collected from depths ≤25 m, including one sample from station F16 (25 m) and two samples from station F17 (1 m, 25 m) in April following a rain event, and a single sample from station F08 (1 m) in October. All of the remaining contaminated samples were collected from depths of 60 m and greater**.** Overall, these results suggest that the wastewater plume was generally restricted to relatively deep waters throughout the year (see Chapter 2).

Interpolations of total coliform data from depths ≥60 suggest that the spatial distribution of the waste field varied by quarter in 2007 (**Figure 3.3)**. During January, for example, the waste field appeared to be fairly well dispersed with the highest bacterial counts occurring at station F20 located to the northeast of the discharge area. The waste field was still well dispersed in April, although the highest bacterial counts appeared to be concentrated immediately around the discharge site (i.e., at station F30). In contrast, the wastewater plume appears to have generally dispersed to the north by

Table 3.5

Summary of indicator bacteria densities (CFU/100 mL) at PLOO offshore stations in 2007. Data for each quarterly survey are expressed as means for all stations along each depth contour; n = total number of samples.

Assay	Contour	n	January	April	July	October
Total	18-m offshore	9	6	2	4	2
	60-m offshore	33	47	129	10	170
	80-m offshore	44	1622	1831	678	205
	98-m offshore	55	1445	1461	1151	863
Fecal	18-m offshore	9	2	2	2	2
	60-m offshore	33	6	22	3	21
	80-m offshore	44	413	195	149	41
	98-m offshore	55	339	309	235	221
Entero	18-m offshore	9	2	2	2	2
	60-m offshore	33	4	5	2	10
	80-m offshore	44	56	34	17	13
	98-m offshore	55	56	46	40	19

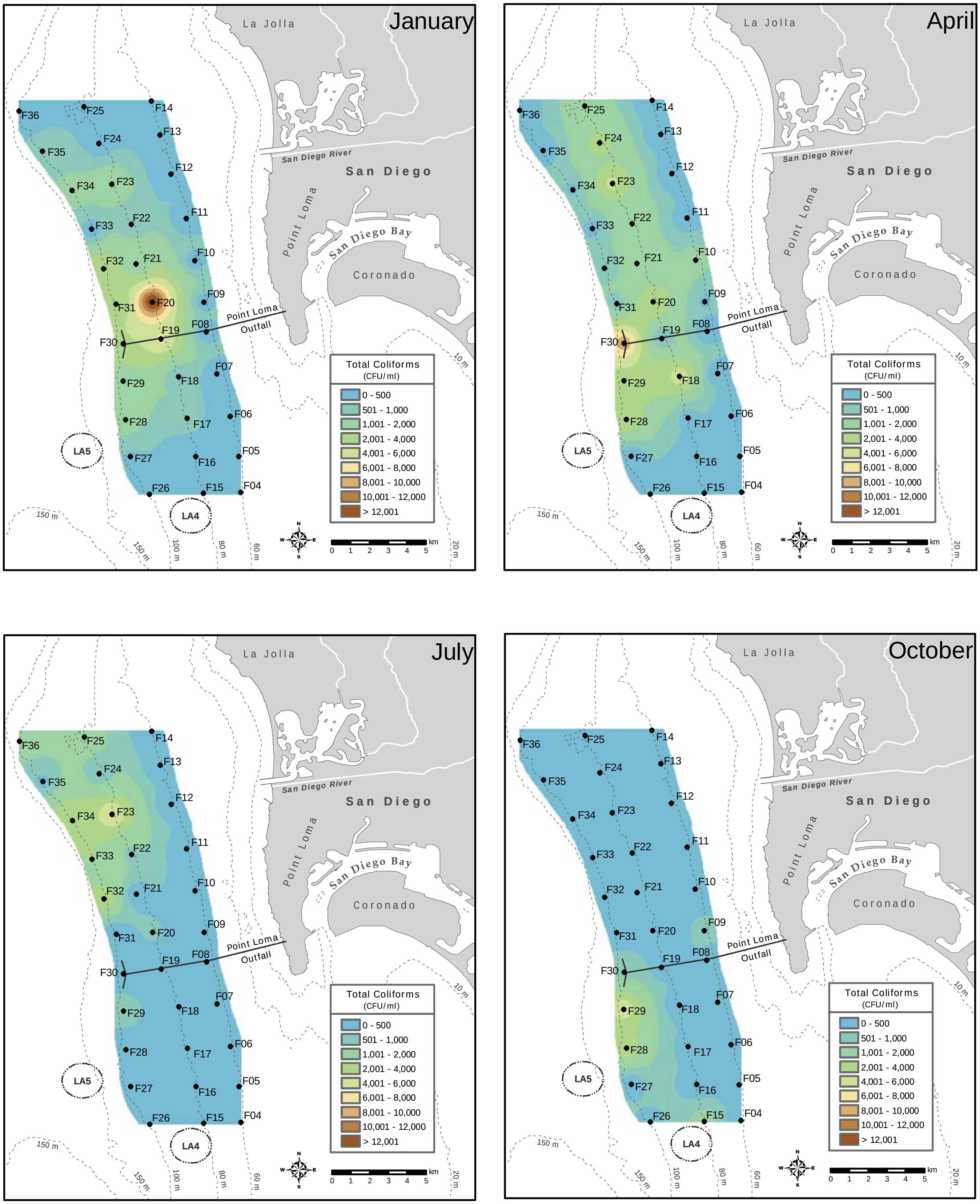

Figure 3.3
Total coliform distributions for seawater samples collected at depths ≥60 m during quarterly offshore surveys in 2007.

July. Finally, results for the October survey indicate that the plume reversed direction and had moved southward, which was consistent with MODIS imagery at the time which showed a southern flow at surface waters (see Svejkovsky 2008).

Compliance with California Ocean Plan Standards

Compliance with COP bacterial standards (Box 3.1) for the shore and kelp stations was very high in 2007 (**Appendices A.2, A.3**). Shore stations D8 and D11 were the only stations with seawater samples where bacteria levels fell below 100% compliance. Station D8, located near a tidally influenced storm drain, was 78% compliant with the 60-day fecal coliform standard, 92% compliant with the fecal geometric mean standard, and 100% compliant with the other two COP standards. Station D11, located near the mouth of the San Diego River, was 92% compliant with the 60-day fecal coliform standard and 100% compliant with the other three COP standards. All seawater samples collected from the kelp stations were 100% compliant with each COP bacterial standard.

Summary and Conclusions

There was no evidence that the Point Loma Ocean Outfall (PLOO) wastewater plume reached the shoreline or recreational waters in 2007. Elevated bacterial densities along the shore were limited to a few instances at stations D4, D7, D8, and D11 where the source of contamination may have been from rainfall, heavy recreational use, or decaying kelp and surfgrass wrack material. For example, most of elevated bacterial densities occurred during the wettest months of 2007 (i.e., February–May, December). Furthermore, all but two shore stations were 100% compliant with the four COP standards; these exceedances also corresponded with rainfall events or were associated with other sources of contamination unrelated to the PLOO.

It is unlikely that the PLOO wastewater ever reached surface waters in 2007. Bacteriological evidence of contaminated water at the offshore stations was predominantly limited to samples collected from depths of 60 m and deeper. The discharge depth (~98 m) may be the dominant factor that keeps the plume from reaching the surface. Wastewater is released into cold, dense seawater that does not appear to mix with the top 25 m of the water column. Analysis of physical parameters during the year suggest that the water column was stratified during the spring through fall months (see Chapter 2). However, the absence of bacteriological contamination in surface waters during January, when the water column was well mixed, suggests that stratification may not be the only factor limiting the depth of the plume to 60 m and deeper.

The dominant direction of waste field flow appeared to be northward in 2007, except during October when it appeared to move in a southerly direction. High bacterial densities were detected at the northern limits of the quarterly sampling grid during most quarters, but only at the most southern sites in October.

Previous analyses of historical water quality data indicate that since the extension of the Point Loma outfall in 1993, the PLOO waste field no longer reaches the shoreline (City of San Diego 2007a). This pattern remained true for 2007 with evidence of the plume being restricted to mostly offshore waters at depths of 60 m or below.

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Chapter 4. Sediment Characteristics

INTRODUCTION

Ocean sediment samples are collected and analyzed as part of the Point Loma Ocean Outfall (PLOO) monitoring program to characterize the surrounding physical environment and assess general sediment conditions. These conditions define the primary habitat for benthic invertebrates that live within or on the surface of sediments and can influence their presence and distribution. In addition, many species of demersal fish are associated with specific sediment types that reflect the habitats of their preferred prey (Cross and Allen 1993). Both natural and anthropogenic factors affect the composition, distribution and stability of seafloor sediments.

Natural factors that affect sediment conditions on the continental shelf include the strength and direction of bottom currents, exposure to wave action, seafloor topography, and proximity to geographic features such as submarine basins, canyons and hills, inputs associated with outflows from rivers and bays, beach erosion and runoff from other terrestrial sources, and decomposition of calcareous organisms (e.g., Emery 1960). The analyses of parameters such as sediment grain size and relative percentages of different sediment fractions (e.g., sand, silt and clay) can provide useful information concerning current velocity, amount of wave action and overall habitat stability in an area. Further, understanding sediment grain size distributions allows for better interpretations of the interactions between benthic organisms and the environment. For example, differences in sediment composition (e.g., fine vs. coarse particles) and associated levels of organic loading at specific sites can affect burrowing, tube building and feeding abilities of infaunal invertebrates, thus leading to changes in benthic community structure (Gray 1981, Snelgrove and Butman 1994). Geological history can also affect the chemical composition of local sediments. For example, erosion from cliffs and shores, and the flushing of sediments and other debris of terrestrial origin from bays, rivers and streams can contribute to the deposition and accumulation of metals in an area and also affect the overall organic content of sediments. Additionally, primary productivity by marine plankton is an important source of organics to the marine benthos (Mann 1982, Parsons et al. 1990). Finally, particle size composition can affect concentrations of chemical constituents within sediments. For example, levels of organic compounds and trace metals within seafloor sediments generally rise with increasing amounts of fine particles (Emery 1960, Eganhouse and Vanketesan 1993).

Municipal wastewater outfalls are one of many anthropogenic factors that can directly influence the composition and distribution of sediments through the discharge of treated effluent and the subsequent deposition of a wide variety of organic and inorganic compounds. Some of the most commonly detected compounds discharged via ocean outfalls are trace metals, pesticides and various organic compounds such as total organic carbon, nitrogen and sulfides (see Anderson et al. 1993). Moreover, the presence of large outfall pipes and their associated ballast materials (e.g., rock, sand) may alter the hydrodynamic regime of surrounding areas.

This chapter presents summaries and analyses of sediment grain size and chemistry data collected during 2007 at monitoring sites surrounding the PLOO. The primary goals are to: (1) assess possible effects of wastewater discharge on benthic habitats by analyzing spatial and temporal variability of various sediment parameters, (2) determine the presence or absence of sedimentary and chemical footprints near the discharge site, and (3) evaluate overall sediment quality in the region.

Materials and Methods

Field Sampling

Sediment samples were collected at 22 benthic stations in the PLOO region during January and

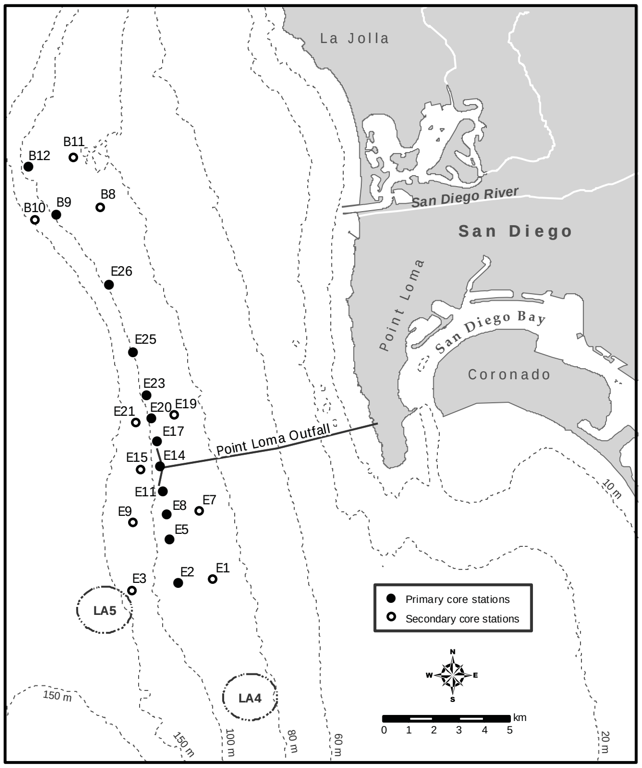

Figure 4.1
Benthic station locations sampled for the Point Loma Ocean Outfall Monitoring Program.

July 2007 (**Figure 4.1**). These stations are located along the 88, 98, and 116-m depth contours, and include 17 "E" stations located within 8 km of the outfall, and five "B" stations located greater than 11 km north of the outfall. Each sediment sample was collected from one side of a chain-rigged double Van Veen grab with a 0.1-m^2 surface area; the other grab sample from the cast was used for macrofaunal community analysis (see Chapter 5). Sub-samples for various analyses were taken from the top 2 cm of the sediment surface and handled according to EPA guidelines (USEPA 1987).

Laboratory Analyses

All sediment chemistry and grain size analyses were performed at the City of San Diego's Wastewater Chemistry Services Laboratory. Particle size analysis was performed using a Horiba LA-920 laser scattering particle analyzer, which measures particles ranging in size from 0.00049 to 2.0 mm (i.e., 11 to -1 phi). Coarser materials (e.g., very coarse sand, gravel, shell hash) were removed prior to analysis by screening the samples through a 2.0-mm mesh sieve. These data were expressed as "% coarse" of the total sample sieved.

Output from the Horiba particle size analyzer was categorized as follows: sand was defined as particles ranging from >0.0625 to 2.0 mm in size, silt as particles from 0.0625 to 0.0039 mm, and clay as particles <0.0039 mm (see **Table 4.1**). These data were standardized and combined with any sieved coarse fraction (i.e., particles >2.0 mm) to obtain a distribution of the coarse, sand, silt and clay fractions totaling 100%. The coarse fraction was included with the ≤2.0 mm fraction in the calculation of various particle size parameters, which were determined using a normal probability scale (see Folk 1968). These parameters were summarized and expressed as overall mean particle size (mm), phi size (mean, median, skewness, and kurtosis), and the proportion of coarse, sand, silt, and clay. The proportion of fine particles (% fines) was calculated as the sum of all silt and clay fractions.

Sediment samples were analyzed for total organic carbon (TOC), total nitrogen (TN), total sulfides, biochemical oxygen demand (BOD), total volatile solids (TVS), trace metals, chlorinated pesticides (e.g., DDT), polychlorinated biphenyl compounds (PCBs), and polycyclic aromatic hydrocarbons (PAHs; see **Appendix B.1**). TOC, TN, and TVS were measured as percent weight (%wt) of the sediment sample; BOD, sulfides and metals were measured in units of mg/kg and expressed as parts per million (ppm); pesticides and PCBs were measured in units of ng/kg and expressed as parts per trillion (ppt); PAHs were measured in units of µg/kg and expressed as parts per billion (ppb). The data reported herein were generally limited to values above the method detection limit (MDL). However, concentrations below MDLs were included as estimated values if the presence of the specific constituent could be verified by mass-spectrometry (i.e., spectral peaks confirmed). A detailed description of the analytical protocols may be obtained from the City of San Diego Wastewater Chemistry Services Laboratory (see City of San Diego 2008).

Table 4.1

A subset of the Wentworth scale representative of the sediments encountered in the PLOO region. Particle size is presented in phi, microns, and millimeters along with the conversion algorithms. The sorting coefficients (standard deviation in phi units) are based on categories described by Folk (1968).

Wentworth scale				Sorting coefficient	
Phi size	Microns	Millimeters	Description	Standard deviation	Sorting
-2	4000	4	Pebble	Under 0.35 phi	very well sorted
-1	2000	2	Granule	0.35–0.50 phi	well sorted
0	1000	1	Very coarse sand	0.50–0.71 phi	moderately well sorted
1	500	0.5	Coarse sand	0.71–1.00 phi	moderately sorted
2	250	0.25	Medium sand	1.00–2.00 phi	poorly sorted
3	125	0.125	Fine sand	2.00–4.00 phi	very poorly sorted
4	62.5	0.0625	Very fine sand	Over 4.00 phi	extremely poorly sorted
5	31	0.0310	Coarse silt		
6	15.6	0.0156	Medium silt		
7	7.8	0.0078	Fine Silt		
8	3.9	0.0039	Very fine silt		
9	2.0	0.0020	Clay		
10	0.98	0.00098	Clay		
11	0.49	0.00049	Clay		

Conversions for diameter in phi to millimeters: $D(mm) = 2^{-phi}$

Conversions for diameter in millimeters to phi: $D(phi) = -3.3219 \log_{10} D(mm)$

Data Analyses

Values for total PAH, total DDT and total PCB were calculated for each sample as the sum of all constituents with reported values. Values for each individual constituent are listed in **Appendix B.2**. Zeroes were substituted for all non-detects (i.e., null values) when calculating means. Summaries of parameters included detection rates (i.e., total number of reported values/total number of samples), annual means by station, annual means for all stations combined (areal mean), and the maximum value of each parameter during the year. Levels of contamination were further evaluated by comparing the results of this study to the Effects Range Low (ERL) sediment quality guidelines of Long et al. (1995) when available. The National Status and Trends Program of the National Oceanic and Atmospheric Administration (NOAA) originally calculated the ERLs to provide a means for interpreting monitoring data. The ERLs are considered to represent chemical concentrations below which adverse biological effects are rarely observed.

Results and Discussion

Particle Size Distribution

During 2007, ocean sediments collected off Point Loma were predominantly composed of very fine sands and coarse silt with mean particle sizes ranging from about 0.04 to 0.12 mm (**Table 4.2**). Differences in intra-station particle size composition between the winter and summer surveys ranged between 0–0.109 mm and 0.1–18.2% fines; the greatest differences occurred at three stations (E2, E3 and E9) located south of the outfall (**Appendix B.3**). Overall, fine sediments averaged about 40% region-wide during the year, ranging narrowly from a low of 29.6% to a high of 60.3% fines at the different stations. Several stations along the 98-m and 116-m depth contours from E21 south to E5 were composed of sediments that were slightly coarser than the

Table 4.2

Summary of particle size parameters and organic loading indicators at PLOO benthic stations during 2007. Data are annual means per station (n=2); SD=standard deviation; BOD=biological oxygen demand; TN=total nitrogen; TOC=total organic carbon; TVS=total volatile solids.

		Particle size						Organic indicators				
	Depth (m)	Mean (mm)	Mean (phi)	SD (phi)	Coarse (%)	Sand (%)	Fines (%)	BOD* (ppm)	Sulfides (ppm)	TN (%wt)	TOC (%wt)	TVS (%wt)
North reference stations												
B11	88	0.052	4.3	1.8	1.6	53.0	45.4	332	0.3	0.071	2.895	3.80
B8	88	0.042	4.6	1.6	0.0	43.2	56.9	300	8.1	0.075	0.901	2.94
B12	98	0.065	4.0	1.8	1.2	63.9	35.0	351	0.2	0.060	3.835	3.33
B9	98	0.051	4.3	1.7	0.0	56.9	43.2	334	1.8	0.063	0.953	2.90
B10	116	0.068	3.9	1.5	0.0	70.5	29.6	351	3.5	0.058	1.415	2.73
Stations north of the outfall												
E19	88	0.049	4.4	1.5	0.0	52.8	47.2	438	9.3	0.068	0.749	2.42
E20	98	0.060	4.1	1.5	0.5	62.2	37.4	325	7.5	0.055	0.643	2.06
E23	98	0.055	4.2	1.5	0.0	59.0	41.0	364	3.2	0.057	0.681	2.27
E25	98	0.058	4.1	1.5	0.0	61.1	39.0	285	6.1	0.050	0.668	2.40
E26	98	0.052	4.3	1.5	0.0	56.3	43.8	349	8.2	0.067	0.770	2.51
E21	116	0.061	4.0	1.5	0.0	66.4	33.6	373	5.9	0.050	0.630	2.01
Near outfall stations												
E11	98	0.074	3.8	1.3	0.0	70.0	30.0	216	10.5	0.045	0.671	1.56
E14	98	0.073	3.8	1.4	0.0	70.5	29.6	492	22.8	0.036	0.439	1.80
E17	98	0.066	3.9	1.4	0.0	67.3	32.8	407	14.8	0.047	0.548	1.87
E15	116	0.064	4.0	1.5	0.0	67.7	32.4	352	10.0	0.052	0.777	2.21
Stations south of the outfall												
E1	88	0.061	4.1	2.0	2.9	57.2	40.0	200	2.6	0.050	0.635	1.98
E7	88	0.055	4.2	1.5	0.0	57.6	42.4	309	8.7	0.034	0.695	2.25
E2	98	0.114	3.2	1.6	7.9	31.9	60.3	347	15.2	0.066	0.878	2.85
E5	98	0.065	4.0	1.5	0.0	65.5	34.5	285	4.2	0.042	0.643	2.06
E8	98	0.067	3.9	1.4	0.0	66.3	33.7	289	46.4	0.047	0.700	2.11
E3	116	0.121	3.2	1.7	5.1	59.3	35.7	221	13.1	0.036	0.507	1.89
E9	116	0.103	3.5	1.8	9.0	43.1	48.0	258	5.6	0.054	1.545	2.44
Detection rate (%)								100	98	98	100	100
Area mean		0.067	4.0	1.5	1.3	59.1	39.6	326	9.5	0.054	1.008	2.38
Area max		0.121	4.6	2.0	9.0	70.5	60.3	626	89.5	0.083	3.900	4.05

*QC standard criteria failed for BOD samples collected in July. Data are reported despite this failure because results were found to be in the range of historical data and the batch failure applied only to seeded bottles (samples are not seeded).

surrounding area (**Figure 4.2**). Field observations of sediment samples from these stations indicated the presence of shell hash and/or coarse black sand (used as stabilizing material for the outfall pipe; Appendix B.3). No major changes to sediment size appeared to occur following the initiation of the wastewater discharge at the end of 1993 (**Figure 4.3**).

The particle size sorting coefficient reflects the range of grain sizes comprising sediments and is calculated as the standard deviation (SD) in phi size units (see Table 4.1). In general, areas composed of particles of similar size are considered to have well-sorted sediments (i.e., SD≤0.5 phi). In contrast, samples with particles of varied sizes are characteristic of poorly sorted sediments (i.e., SD≥1.0 phi). Sediments in the Point Loma region were poorly sorted in 2007 with sorting coefficients ranging from 1.3 to 2.0 phi (Table 4.2). These results are typical of the mid-shelf and reflect

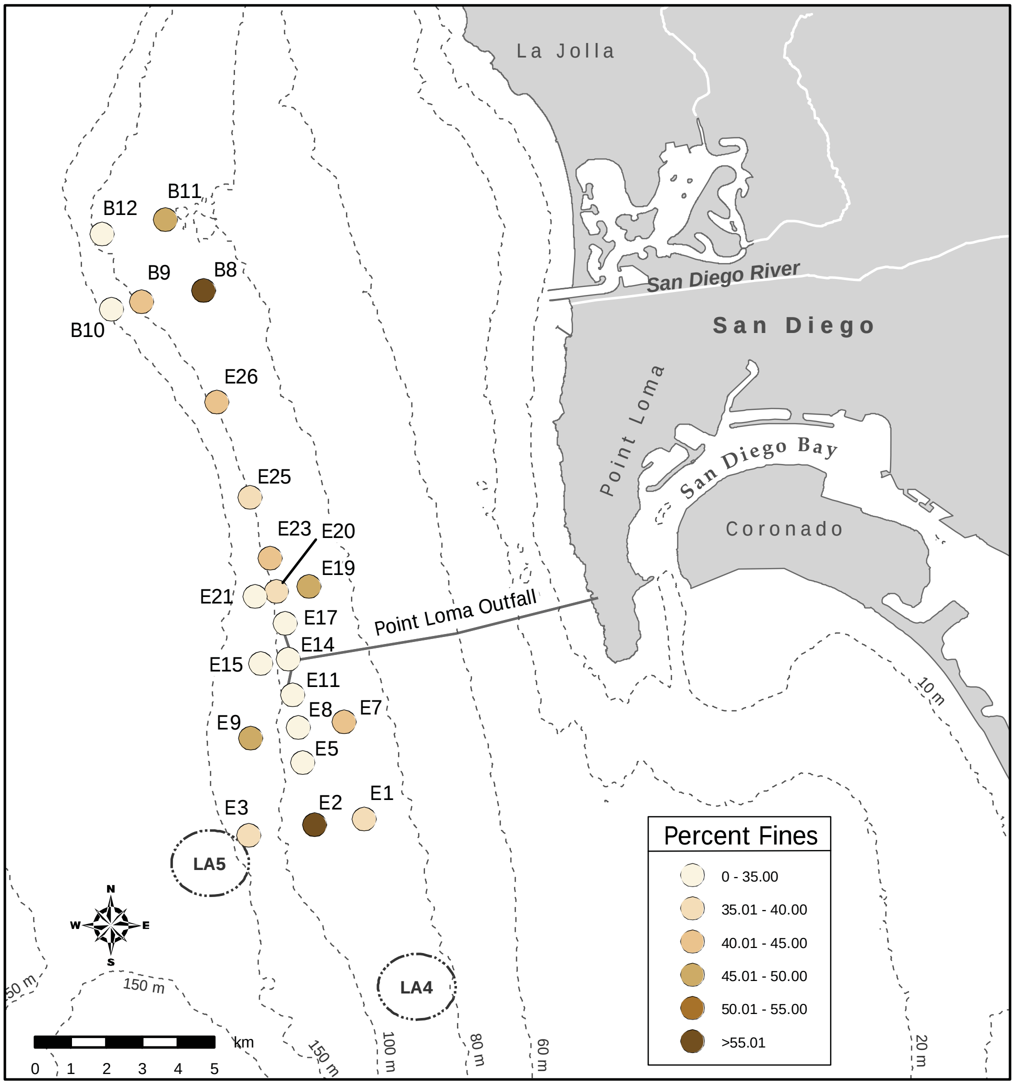

Figure 4.2

Particle size distribution for PLOO benthic stations sampled during 2007. Data are annual means (n=2).

the multiple origins of sediments in the region (see Emery 1960, City of San Diego 2007a). This also suggests that these sites are not subject to fast moving currents or large disturbances (e.g., storm surge, rapid suspension/deposition of materials).

Indicators of Organic Loading

Generally, the distribution of organic indicators in PLOO sediments during 2007 was similar to that seen prior to discharge (see City of San Diego 1995a). Detection rates were ≥98% for biochemical oxygen demand (BOD), total organic carbon (TOC), total nitrogen (TN), sulfides, and total volatile solids (TVS) (Table 4.2). With the exception of perhaps sulfides and BOD, concentrations of most indicators at stations nearest the discharge site (e.g., stations E11, E14, E15 and E17) were similar to values reported elsewhere in the region. For example, the highest concentrations of TOC, TN, and TVS occurred in sediments from three of the northern reference stations (i.e., B12, B8 and B11, respectively). Only sulfides, and to a lesser extent BOD, have demonstrated noticeable changes near the outfall that appear to be coincident the initiation of wastewater discharge (see Figure 4.3 and City of San Diego 2007b).

Trace Metals

Aluminum, arsenic, barium, chromium, copper, iron, lead, manganese, mercury, nickel, tin and zinc were

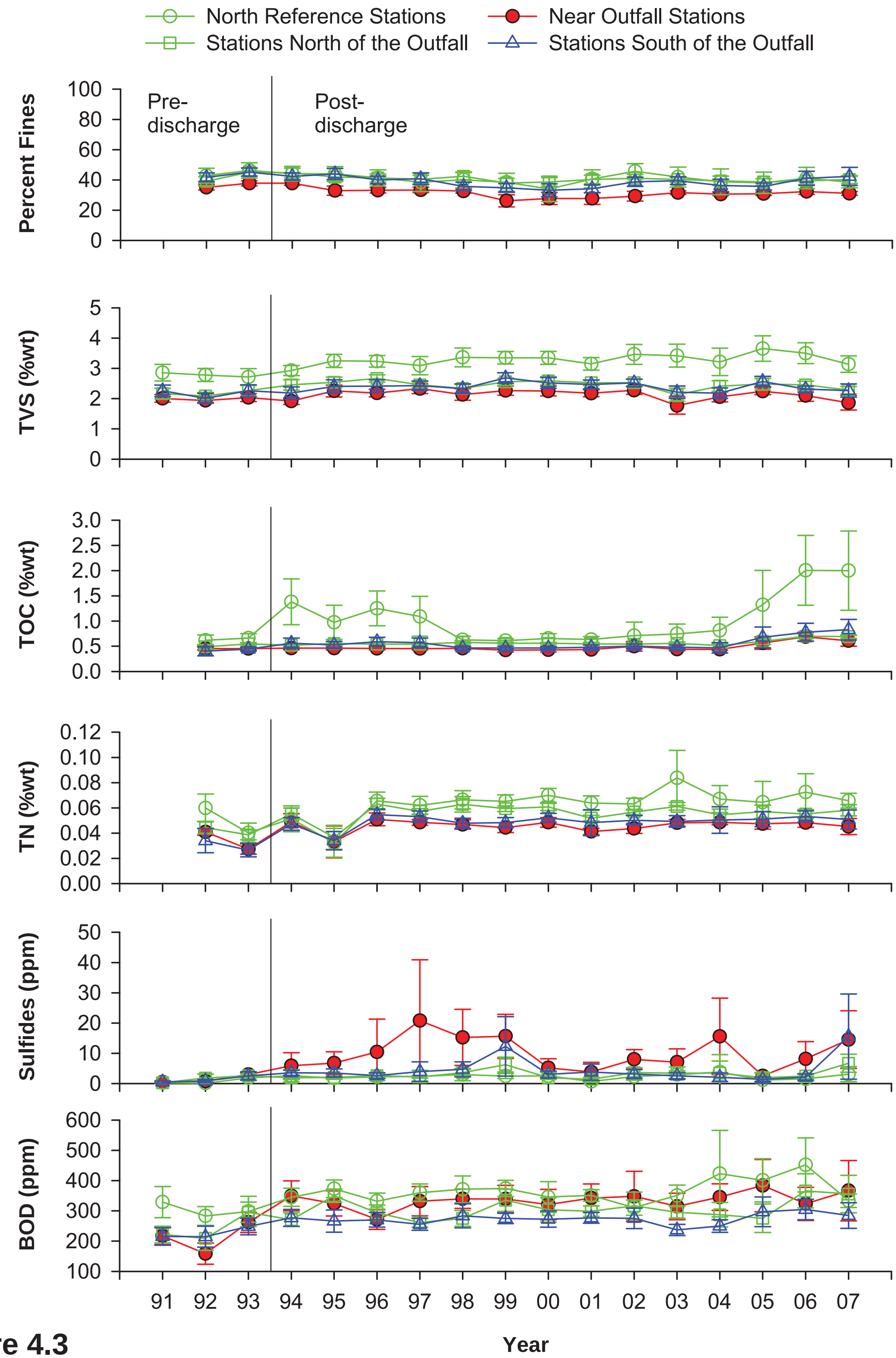

Figure 4.3
Summary of particle size and organic indicator data surrounding the PLOO from 1991–2007: BOD=biological oxygen demand, TN=total nitrogen, TOC=total organic carbon, TVS=total volatile solids, %wt=percent weight. Data are expressed as means pooled over all stations in each station group (see Table 4.2; n=≤14); error bars represent 95% confidence limits.

detected in 100% of the sediment samples collected in the Point Loma region during 2007 (**Table 4.3**). Other metals that were detected in at least 50% of the samples included antimony, cadmium, silver and thallium; selenium was detected in 34% of the samples; beryllium was not detected at all. Concentrations of each metal were variable. The highest average concentrations of almost all of the metals occurred in sediments from the north references stations and/or the stations south of the outfall. For example, station E3, located closest to the LA-5 dumpsite, had sediments with the highest concentrations of copper, lead, mercury, and zinc. In contrast, none of the highest concentrations occurred in the sediments closest to the PLOO. Of all the metals, only silver exceeded environmental threshold values during the year; i.e., the ERL for silver was exceeded at several stations throughout the region, but not at stations closest to the outfall.

Pesticides

Chlorinated pesticides were detected in up to 70% of the samples collected from PLOO stations in 2007 (**Table 4.4**, Appendix B.2). Total DDT (primarily p,p-DDE) was the most prevalent pesticide, occurring in sediments from all stations at concentrations averaging between 60–440 ppt (Table 4.4). Concentrations of total DDT were lower than the ERL of 1580 ppt for this pesticide. Another pesticide detected during the year was hexachlorobenzene (HCB), which occurred in concentrations averaging 33–400 ppt. This pesticide was detected in 30% of the samples at a total of 10 different sites located either to the north or the south of the PLOO. Two other pesticides were also detected, but in only single samples. These included BHC (beta isomer) in a sample from station E3 in January, and heptachlor detected in sediments at station E26 in July (Appendix B.2). As with the metals, pesticide values showed no patterns relative to wastewater discharge.

PCBs and PAHs

PCBs were detected in 32% of the sediment samples collected from eleven stations in 2007, most of which were located to the south of the PLOO (Table 4.4). Total PCB concentrations were highest in sediments from the three sites located immediately adjacent to (i.e., station E3) or further to the east of the LA-5 dredge disposal site (i.e., stations E2 and E1), and from one station (E9) located between LA-5 and the PLOO discharge site. Sediments from each of these stations also had the greatest number of PCB congeners that were detected (e.g., up to 28/sample; see Appendix B.2). PCBs have historically occurred at these and other stations located relatively near the LA-5 disposal site.

In contrast to PCBs, low levels of various PAH compounds were detected in all samples analyzed for 2007 (Table 4.4). All total PAH values were less than the ERL of 4022 ppt. The most prevalent PAHs were 1-methylnapthalene, 2,6-dimethylnapthalene, 2-methylnaphthalene, benzo(A)anthracene, biphenyl, naphthalene, and phenanthrene (Appendix B.2). Each of these PAHs was detected in at least 40% of the samples. There was no apparent relationship between PAH concentrations and proximity to the outfall discharge site.

Summary and Conclusions

Ocean sediments at stations surrounding the PLOO in 2007 were comprised primarily of very fine sands and coarse silt. Overall, these sediments were poorly sorted and consisted of particles of varied sizes. This suggests that the region was subject to low wave and current activity and/or physical disturbance. Several stations along the 98-m and 116-m depth contours were composed of sediments that were slightly coarser than the surrounding area. Field observations of sediment samples from these stations indicated the presence of shell hash and/or coarse black sand. Overall, differences in the particle size composition of sediments off Point Loma are likely affected by both anthropogenic and natural influences, including outfall construction materials, the offshore disposal of dredged materials, the multiple geological origins of specific sediment types, and recent deposits of detrital materials (e.g., see Emery 1960).

Table 4.3

Concentrations of trace metals (ppm) detected at each PLOO benthic station during 2007. Data are annual means (n=2); ERL=effects range low threshold value; na=not available; nd=not detected. See Appendix B for MDLs and names for each metal represented by periodic table symbol.

Station	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
North reference stations																		
B11	12150	0.39	3.5	48.0	nd	0.074	25.0	5.3	20500	3.5	141.0	0.028	9.1	0.360	0.91	0.128	1.51	40.0
B8	14550	0.37	2.8	53.1	nd	0.060	23.1	6.9	16900	2.6	140.5	0.041	10.3	0.207	2.97	0.682	1.83	37.9
B12	8320	0.42	4.2	26.0	nd	0.083	27.6	1.3	22950	2.5	84.0	0.021	6.9	0.329	nd	nd	1.17	36.8
B9	11900	0.44	2.8	67.5	nd	0.060	25.0	4.3	19000	2.9	121.5	0.028	8.6	0.127	1.85	0.263	1.80	38.3
B10	9115	0.31	2.5	30.4	nd	0.066	19.3	3.7	14200	2.2	91.6	0.018	6.4	0.133	0.95	0.199	1.37	29.8
Stations north of the outfall																		
E19	12650	0.25	3.3	47.9	nd	0.044	19.1	6.6	13950	2.8	118.0	0.035	8.3	0.265	2.00	0.483	1.56	32.4
E20	9910	0.15	2.4	33.8	nd	0.083	15.8	5.2	11600	1.5	95.4	0.020	7.2	nd	1.32	0.628	1.13	28.2
E23	10955	0.12	2.1	40.5	nd	0.070	17.6	5.9	12650	2.6	104.3	0.028	7.7	nd	1.44	0.565	1.45	29.1
E25	11450	0.40	2.5	41.9	nd	0.062	19.0	5.7	13950	2.5	124.5	0.030	8.2	nd	2.95	0.747	1.77	29.5
E26	11700	0.36	3.0	42.0	nd	0.051	19.3	5.6	14050	2.7	123.0	0.031	8.5	0.221	2.58	0.825	1.60	31.0
E21	8560	0.13	2.6	27.2	nd	0.050	14.0	4.5	9960	2.1	80.2	0.021	6.0	nd	1.06	0.363	1.00	23.6
Near outfall stations																		
E11	8130	0.13	2.4	27.9	nd	0.050	14.1	4.2	10315	1.8	81.0	0.018	6.0	nd	0.56	0.121	1.21	22.4
E14	7120	0.10	2.3	26.6	nd	0.066	13.3	4.1	9485	1.6	73.5	0.015	5.8	0.127	0.41	0.408	1.08	21.5
E17	7845	0.15	3.0	28.5	nd	0.067	14.1	4.6	10250	1.9	78.9	0.022	6.1	nd	0.53	0.294	1.07	22.1
E15	8470	0.20	2.1	28.9	nd	0.073	15.7	5.5	10850	2.5	80.8	0.020	6.4	0.145	0.55	0.213	1.31	25.5
Stations south of the outfall																		
E1	12650	0.11	2.6	45.3	nd	nd	18.9	7.6	14200	3.9	116.5	0.060	7.3	nd	1.06	0.943	1.37	32.4
E7	11405	0.14	2.5	42.3	nd	0.074	17.8	5.9	13050	2.7	106.8	0.034	7.7	nd	1.73	0.361	1.36	32.5
E2	17500	0.24	2.9	77.1	nd	nd	23.9	11.7	21350	3.1	152.0	0.053	9.2	nd	1.30	0.909	1.32	36.7
E5	9345	0.28	2.0	32.3	nd	0.059	15.1	4.7	11050	1.8	90.1	0.026	6.4	0.137	0.97	0.621	1.24	26.6
E8	10280	0.18	2.1	38.5	nd	0.066	16.7	5.5	11950	2.7	96.0	0.026	7.3	0.121	0.77	0.393	1.69	26.8
E3	11650	0.22	2.8	54.0	nd	0.037	16.6	13.3	14200	6.8	108	0.071	6.6	0.195	1.12	0.602	1.38	40.6
E9	8410	0.30	3.6	30.1	nd	0.055	17.8	6.9	12550	2.8	76.6	0.025	6.7	nd	0.35	0.136	1.16	34.6
Detection rate (%)	100	55	100	100	0	91	100	100	100	100	100	100	100	34	77	75	100	100
Area mean	10639	0.25	2.7	40.5	nd	0.058	18.6	5.9	14044	2.7	103.8	0.031	7.4	0.108	1.25	0.450	1.38	30.8
Area max	18300	0.88	4.5	78.8	nd	0.107	28.7	14.2	24200	8.4	154.0	0.095	10.9	0.443	5.84	1.390	2.11	44.9
ERL	na	na	8.2	na	na	1.200	81.0	34.0	na	46.7	na	0.200	20.9	na	1.00	na	na	150.0

Table 4.4

Concentrations of total DDT, hexachlorobenzene (HCB), total PCB, and total PAH at PLOO benthic stations in 2007. DDT, HCB and PCB data are expressed in parts per trillion (ppt), while PAH data are expressed in parts per billion (ppb).

Station	tDDT	HCB	tPCB	tPAH
North reference stations				
B11	145	135	—	243.4
B8	158	150	15	116.2
B12	60	385	—	77.0
B9	75	—	—	111.1
B10	70	—	—	107.2
Stations north of the outfall				
E19	358	—	10	98.4
E20	275	—	—	79.8
E23	380	—	151	148.9
E25	108	—	—	88.5
E26	165	385	—	91.7
E21	250	—	—	84.6
Near outfall stations				
E11	80	—	41	79.1
E14	65	—	—	103.3
E17	280	—	34	81.7
E15	70	—	—	106.0
Stations south of the outfall				
E1	440	50	4113	104.0
E7	395	—	42	98.5
E2	360	235	517	101.6
E5	110	150	50	94.9
E8	95	80	—	66.4
E3	140	400	6136	80.8
E9	200	33	491	66.7
Detection rate (%)	70	30	32	100

Concentrations of various contaminants, including most indicators of organic loading (e.g., TN, TOC, TVS), trace metals, pesticides (e.g., DDT), PCBs and PAHs in sediments off Point Loma remained within the natural range of variability for San Diego and other areas of the southern California continental shelf (see Schiff and Gossett 1998, Noblet et al. 2003, Schiff et al. 2006). The only metal that exceeded ERL values for southern California was silver, which was present in relatively high concentrations throughout the region. Most of these contaminants were detected rarely or in low concentrations during 2007. For example, PCBs and various chlorinated pesticides (HCB, BHC and heptachlor) had detection rates ≤32% during the year. Although DDT and PAHs were detected in sediments at most stations, these compounds were present at concentrations below their respective ERLs.

There were few clear patterns in sediment contaminant concentrations relative to the PLOO discharge site in 2007 other than the typical slightly higher sulfide and BOD levels. Instead, the highest concentrations of several organic indicators, metals and PCBs were found in sediments from the southern and/or northern-most stations. These included the highest concentrations of copper, lead, mercury, zinc and total PCBs in sediments near the LA-5 disposal site. In general, concentrations of contaminants have been higher at these southern stations than elsewhere off San Diego, and are most likely the result of misplaced deposits of dredged material that were originally destined for LA-5. Previous studies have attributed elevated levels of various contaminants such as PAHs, PCBs, trace metals, and DDT in this area to the deposits from LA-5 (see Anderson et al. 1993; City of San Diego 2003; Steinberger et al. 2003), while many were also present in high concentrations in sediments collected from San Diego Bay (see City of San Diego 2003).

Wastewater discharge does not appear to be significantly impacting sediment quality in the vicinity of the PLOO after 14 years of outfall operation. Overall, there is little or no evidence of organic and contaminant loading in the region, with measured parameters existing at levels within the range of natural variability for reference areas throughout the Southern California Bight (e.g., see City of San Diego 2007b). The only sustained effects have been restricted to mostly a few sites located nearest the PLOO discharge site, including station E14 near the center of the outfall wye, and stations E11 and E17 located near the ends of the southern and northern diffuser legs, respectively. These effects include an in increase in sediment particle size through time, measurable increases in sulfide concentrations, and smaller increases in BOD. However, there is no evidence that the outfall discharge is affecting the quality of benthic sediments to the point that it will degrade the resident marine biota (e.g., also see Chapter 5).

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Chapter 5. Macrobenthic Communities

INTRODUCTION

Benthic macroinvertebrates along the coastal shelf of southern California represent a diverse faunal community that is important to the marine ecosystem (Fauchald and Jones 1979, Thompson et al. 1993a, Bergen et al. 2001). These animals serve vital functions in wide ranging capacities. Some species decompose organic material as a crucial step in nutrient cycling, other species filter suspended particles from the water column, thus affecting water clarity. Many species of benthic macrofauna also are essential prey for fish and other organisms.

Human activities that impact the benthos can sometimes result in toxic contamination, oxygen depletion, nutrient loading, or other forms of environmental degradation. Certain macrofaunal species are sensitive to such changes and rarely occur in impacted areas, while others are opportunistic and can thrive under altered conditions. Because various species respond differently to environmental stress, monitoring macrobenthic assemblages can help to identify anthropogenic impacts (Pearson and Rosenberg 1978, Bilyard 1987, Warwick 1993, Smith et al. 2001). Also, since the animals in these assemblages are relatively stationary and long-lived, they can integrate local environmental conditions (Gray 1979). Consequently, the assessment of benthic community structure is a major component of many marine monitoring programs, which are often designed to document both existing conditions and trends over time.

Overall, the structure of benthic communities may be influenced by many factors including depth, sediment composition and quality (e.g., grain size distribution, contaminant concentrations), oceanographic conditions (e.g., temperature, salinity, dissolved oxygen, ocean currents), and biological factors (e.g., food availability, competition, predation). For example, benthic assemblages on the coastal shelf off San Diego typically vary along sediment particle size and/or depth gradients. Therefore, in order to determine whether changes in community structure are related to human impacts or to natural events, it is necessary to have an understanding of background or reference conditions for an area. Such information is available for the monitoring area surrounding the Point Loma Ocean Outfall (PLOO) and the San Diego region in general (e.g., see City of San Diego 1999, 2007b).

This chapter presents analyses and interpretations of the macrofaunal data collected at fixed stations surrounding the PLOO during 2007. Descriptions and comparisons of the different macrofaunal assemblages that inhabit soft bottom habitats in the region and analysis of benthic community structure are included.

Materials and Methods

Collection and Processing of Samples

Benthic samples were collected during January and July 2007 at 22 stations surrounding the PLOO (**Figure 5.1**). These stations are located along the 88, 98, and 116-m depth contours and range from about 8 km south to 11 km north of the outfall.

Samples for benthic community analyses were collected from two replicate 0.1-m^2 van Veen grabs per station during the 2007 surveys. An additional grab was collected at each station for sediment quality analysis (see Chapter 4). The criteria to ensure consistency of grab samples established by the United States Environmental Protection Agency (USEPA) were followed with regard to sample disturbance and depth of penetration (USEPA 1987). All samples were sieved aboard ship through a 1.0-mm mesh screen. Organisms retained on the screen were collected and relaxed for 30 minutes in a magnesium sulfate solution and then fixed in buffered formalin. After a minimum of 72 hours, each sample was rinsed with fresh water and transferred to 70% ethanol. All animals were sorted

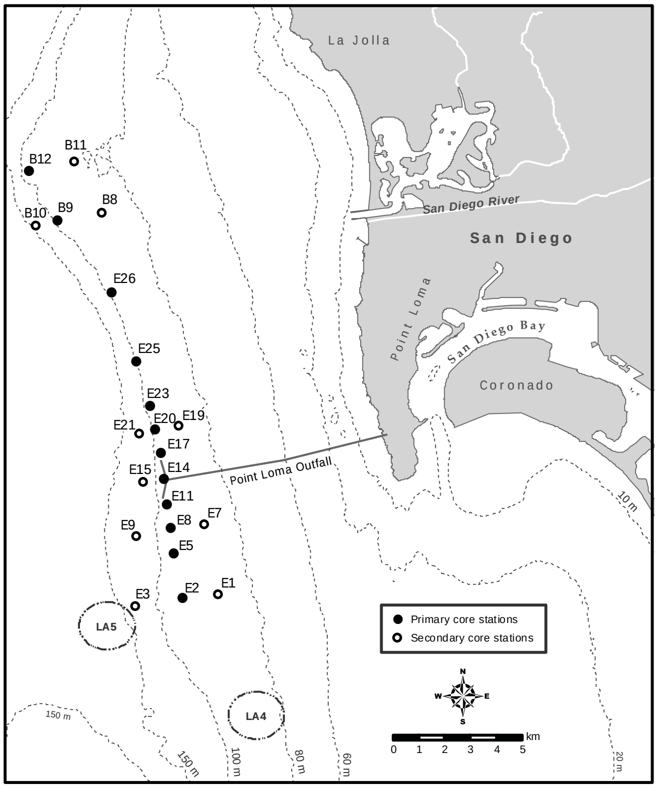

Figure 5.1
Benthic station locations, Point Loma Ocean Outfall Monitoring Program.

from the debris into major taxonomic groups by a subcontractor and then identified to species or the lowest taxon possible and enumerated by City of San Diego marine biologists.

Data Analyses

The following community structure parameters were calculated for each station per 0.1-m^2 grab: species richness (number of species), abundance (total number of individuals), Shannon diversity index (H'), Pielou's evenness index (J'), Swartz dominance (minimum number of species accounting for 75% of the total abundance in each grab; see Swartz et al. 1986, Ferraro et al. 1994), Infaunal Trophic Index (ITI; see Word 1980), and Benthic Response Index (BRI; see Smith et al. 2001). Additionally, the total or cumulative number of species over all grabs was calculated for each station.

Multivariate analyses were performed using PRIMER software to examine spatio-temporal patterns in the overall similarity of benthic assemblages in the region (see Clarke 1993, Warwick 1993). These analyses included classification (cluster analysis) by hierarchical agglomerative clustering with group-average linking and ordination by non-metric multidimensional scaling (MDS). The macrofaunal abundance data were square-root transformed and the Bray-Curtis measure of similarity was used as the basis for both classification and ordination. SIMPER analysis was used to identify individual species that typified each cluster group. Patterns in the distribution of macrofaunal assemblages were compared to environmental variables by overlaying the physico-chemical data onto MDS plots based on the biotic data (see Field et al. 1982).

A BACIP (Before-After-Control-Impact-Paired) statistical model was used to test the null hypothesis that there have been no changes in select community parameters due to operation of the PLOO (see Bernstein and Zalinski 1983, Stewart-Oaten et al. 1986, 1992, Osenberg et al. 1994). The BACIP model tests differences between control (reference) and impact sites at times before (i.e., July 1991–October 1993) and after (i.e., January 1994–July 2007) an impact event (i.e., the onset of discharge). The analyses presented in this report are based on 2.5 years (10 quarterly surveys) of before impact data and 13.5 years (47 quarterly or semi-annual surveys) of after impact data. The E stations, located within 8 km of the outfall, are considered most likely to be affected by wastewater discharge. Station E14 was selected as the impact site for all analyses; this station is located nearest the Zone of Initial Dilution (ZID) and probably is the site most susceptible to impact. In contrast, the B stations are located farther from the outfall (>11 km) and are the obvious candidates for reference or control sites. However, benthic communities differed between the B and E stations prior to discharge (Smith and Riege 1994, City of San Diego 1995). Thus, two stations (E26 and B9) were selected to represent separate control sites in the BACIP tests. Station E26 is located 8 km from the outfall and is considered the E station least likely to be impacted. Previous analyses suggested that station B9 was one of the most appropriate B stations for comparison with the E stations (Smith and Riege 1994, City of San Diego 1995). Six dependent variables were analyzed, including three community parameters (number of species, infaunal abundance, BRI) and abundances of three taxa that are considered sensitive to organic enrichment. These indicator taxa include ophiuroids in the genus *Amphiodia* (mostly *A. urtica*), and amphipods in the genera *Ampelisca* and *Rhepoxynius*. All BACIP analyses were interpreted using a Type I error rate of α=0.05.

Results and Discussion

Community Parameters

Species richness

A total of 565 macrofaunal taxa were identified during the 2007 PLOO surveys. Mean values of species richness ranged from 65 to 114 species per 0.1 m^2 (**Table 5.1**). Stations B11, B10 and E3 were characterized by the most species, averaging 100–114 species per grab. This pattern is consistent with previous species richness values for these sites (e.g., City of San Diego 2006, 2007a) In contrast, the lowest species richness was found at stations B8 and E21, which averaged 65 and 71 species per sample, respectively. In addition, species richness at more than half of the stations showed a general decrease compared to 2006 (see City of San Diego 2007a).

Macrofaunal abundance

Macrofaunal abundance averaged 207–410 animals B11, E1 and E25 were also relatively high, averaging 325–334 animals per sample. The fewest animals (<225 per 0.1 m^2) were collected at stations B8, B9, E21 and E23. The remaining sites had abundances ranging from 233 to 316 animals per grab. Overall, there was a 21% decrease in macrofaunal abundance at the PLOO sites between 2006 and 2007, with the largest difference occurring at station B12 (see City of San Diego 2007a). This site averaged 504 and 289 individuals per grab in 2006 and 2007, respectively.

Species diversity, dominance, and evenness

Species diversity (H') ranged from 3.4 to 4.2 during the year (Table 5.1), which was similar to that observed prior to wastewater discharge (see City of San Diego 1995). The highest diversity (H' ≥4.1) occurred at the northern stations B10 and B11, while the lowest diversity (H' ≤3.5) occurred at stations E1 and B8.

Dominance was expressed as the Swartz 75% dominance index, which equals the minimum number of species comprising 75% of a community by abundance. Therefore, lower index values (i.e., fewer species) indicate higher numerical dominance. Benthic assemblages in 2007 were characterized by relatively high numbers of evenly distributed species with index values averaging 32 species per station (Table 5.1). The lowest dominance (values ≥40) occurred at stations B10 and B11, while the highest dominance value of 23 species was seen for the assemblages at stations B8 and E1. Evenness (J') values averaged from 0.78 to 0.91 at the different stations during the year.

Environmental disturbance indices

Benthic response index (BRI) values averaged from 6 to 21 at the various PLOO stations in 2007 (Table 5.1). These values suggest that benthic communities in the region are relatively undisturbed as BRI values below 25 are considered indicative of reference conditions (Smith et al. 2001). The highest mean values (≥15) were measured at stations E11, E14, and E17 located nearest the discharge site. Mean infaunal trophic index (ITI) values ranged from 65 to 87 per station in 2007 (Table 5.1), which is similar to values reported in previous years (see City of San Diego 2006, 2007a). These relatively high ITI values (i.e., >60) are also indicative of undisturbed sediments or reference environmental conditions (see Bascom et al. 1979).

Dominant Species

Macrofaunal communities in the Point Loma region were dominated by polychaete worms in 2007 (**Table 5.2**). For example, seven polychaete, two crustacean, one echinoderm, and one mollusc species were among the most dominant macroinvertebrates sampled during the year. Polychaetes were the most

Table 5.1

Summary of macrobenthic community parameters for PLOO stations sampled during 2007. SR = species richness, no. species/0.1 m^2; Tot Spp = cumulative no. species for the year; Abun = abundance, no. individuals/0.1 m^2; H' = Shannon diversity index; J' = Evenness; Dom = Swartz dominance, (see text); BRI = benthic response index; ITI = infaunal trophic index. Data are expressed as annual means (n=4).

Station	SR	Tot Spp	Abun	H'	J'	Dom	BRI	ITI
88-m contour								
B11	114	247	334	4.2	0.89	46	7	81
B8	65	127	207	3.5	0.83	23	6	87
E19	89	180	316	3.8	0.85	30	12	80
E7	88	161	311	3.9	0.86	32	9	84
E1	82	161	330	3.4	0.78	23	12	86
98-m contour								
B12	91	185	289	3.9	0.87	31	13	73
B9	80	164	221	3.9	0.90	32	8	78
E26	84	153	264	3.9	0.89	32	11	78
E25	90	167	325	3.9	0.87	31	11	76
E23	80	152	222	4.0	0.91	34	11	79
E20	84	162	233	4.0	0.90	35	13	79
E17	83	157	283	3.8	0.87	30	17	73
E14	96	181	410	3.8	0.83	29	21	65
E11	84	160	282	3.9	0.87	30	15	75
E8	81	160	248	3.9	0.89	32	10	78
E5	81	154	261	3.8	0.87	30	11	78
E2	97	186	292	4.0	0.88	36	8	83
116-m contour								
B10	100	211	289	4.1	0.89	40	12	74
E21	71	153	212	3.8	0.89	27	12	78
E15	80	158	296	3.7	0.85	26	13	77
E9	97	201	299	4.0	0.88	36	8	79
E3	100	204	295	4.0	0.87	38	7	77
All stations								
Mean	87	172	283	3.9	0.87	32	11	78
Std error	2	6	8	0.1	0.01	1	1	1
Min	65	127	207	3.4	0.78	23	6	65
Max	114	247	410	4.2	0.91	46	21	87

diverse of the major taxa, accounting for 50% of all species collected. Crustaceans accounted for 25% of the species, molluscs 14%, echinoderms 6%, and all other taxa combined for 5% of the species. Polychaetes were also the most numerous animals, accounting for 52% of the total abundance. Crustaceans accounted for 21%, echinoderms 13%, molluscs 12%, and all other phyla combined 2%. The most obvious change in benthic community structure was a decrease in polychaete abundances compared to 2006 with polychaete numbers decreasing by 5% overall. The largest decreases in polychaete abundance occurred at northern stations B8 (26%) and E23 (16%). In contrast, mollusc abundances increased throughout the region. The largest increase in mollusc populations occurred at stations B8 (16%) and E26 (12%).

The two most abundant species were the capitellid polychaete *Mediomastus* sp and the ophiuroid *Amphiodia urtica*, each averaging >20 individuals per 0.1 m^2. However, since juvenile ophiuroids usually

Table 5.2
Dominant macroinvertebrates at the PLOO benthic stations sampled during 2007. The 10 most abundant species overall, 10 most abundant species per occurrence, and the 10 most frequently collected (or widely distributed) species are included. Abundance values are expressed as mean number of individuals per 0.1 m^2.

Species	Higher taxa	Abundance per sample	Abundance per occurence	Percent occurence
Most abundant				
Mediomastus sp	Polychaeta: Capitellidae	25.1	25.1	100
Amphiodia urtica	Echinodermata: Ophiuroidea	20.2	20.2	100
Prionospio jubata	Polychaeta: Spionidae	12.0	12.0	100
Euphilomedes producta	Crustacea: Ostracoda	9.1	9.3	98
Aricidea catherinae	Polychaeta: Paraonidae	8.5	8.9	95
Amphiodia sp	Echinodermata: Ophiuroidea	8.0	8.0	100
Lumbrineris sp group I	Polychaeta: Lumbrineridae	6.4	6.9	93
Chaetozone hartmanae	Polychaeta: Cirratulidae	6.2	6.2	100
Axinopsida serricata	Mollusca: Bivalvia	6.1	6.6	93
Ampelisca pacifica	Crustacea: Amphipoda	5.7	5.7	100
Most abundant per occurence				
Mediomastus sp	Polychaeta: Capitellidae	25.1	25.1	100
Amphiodia urtica	Echinodermata: Ophiuroidea	20.2	20.2	100
Prionospio jubata	Polychaeta: Spionidae	12.0	12.0	100
Euphilomedes producta	Crustacea: Ostracoda	9.1	9.3	98
Aricidea catherinae	Polychaeta: Paraonidae	8.5	8.9	95
Amphiodia sp	Echinodermata: Ophiuroidea	8.0	8.0	100
Capitella capitata complex	Polychaeta: Capitellidae	1.5	7.6	20
Lumbrineris sp group I	Polychaeta: Lumbrineridae	6.4	6.9	93
Axinopsida serricata	Mollusca: Bivalvia	6.1	6.6	93
Chaetozone hartmanae	Polychaeta: Cirratulidae	6.2	6.2	100
Most frequently collected				
Mediomastus sp	Polychaeta: Capitellidae	25.1	25.1	100
Amphiodia urtica	Echinodermata: Ophiuroidea	20.2	20.2	100
Prionospio jubata	Polychaeta: Spionidae	12.0	12.0	100
Amphiodia sp	Echinodermata: Ophiuroidea	8.0	8.0	100
Chaetozone hartmanae	Polychaeta: Cirratulidae	6.2	6.2	100
Ampelisca pacifica	Crustacea: Amphipoda	5.7	5.7	100
Euphilomedes producta	Crustacea: Ostracoda	9.1	9.3	98
Amphiuridae	Echinodermata: Ophiuroidea	5.1	5.2	98
Sternaspis fossor	Polychaeta: Sternaspidae	3.2	3.2	98
Aricidea catherinae	Polychaeta: Paraonidae	8.5	8.9	95

cannot be identified to species and are recorded at the generic or familial level (i.e., *Amphiodia* sp or Amphiuridae, respectively), this number underestimates actual populations of *A. urtica*. If values for total *A. urtica* abundance are adjusted to include these unidentified individuals, the estimated density of this species increases to 28 per grab sample, similar to that observed in 2006.

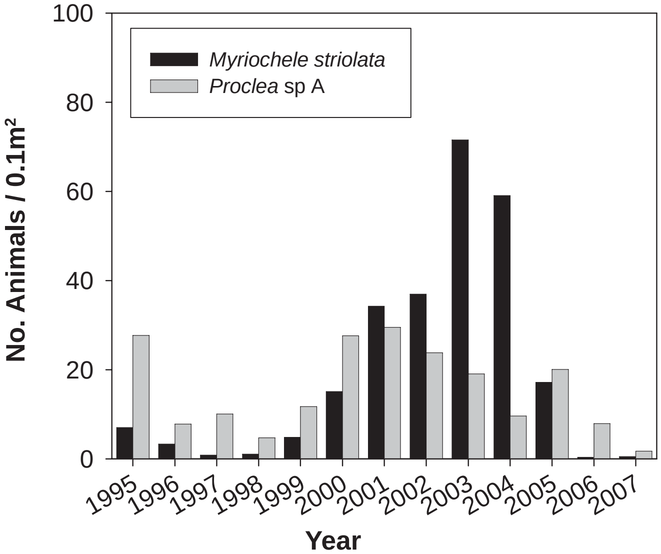

Figure 5.2

Average abundance of the polychaetes, *Myriochele striolata* and *Proclea* sp A at PLOO benthic stations from 1995–2007.

Many of the abundant species in 2007 were also dominant prior to discharge and ever since (e.g., City of San Diego 1995, 1999, 2006, 2007a). For example, *Amphiodia urtica* has been among the most abundant and most commonly occurring species along the outer shelf since sampling began. However, densities of some numerically dominant polychaetes such as the oweniid *Myriochele striolata* and the terebellid *Proclea* sp A have been more cyclical (**Figure 5.2**). For instance, both of these species were among the most abundant polychaetes between 1999–2005, while their densities have decreased during the last two years to levels similar to those observed in 1996–1998. Such variation can have significant effects on other descriptive statistics (e.g., dominance, diversity, and abundance) or environmental indices such as BRI and ITI that use the abundance of indicator species in their equations.

BACIP Analyses

BACIP t-tests indicate that there has been a net change in the mean difference of species richness, BRI values, and *Amphiodia* spp abundance between impact site E14 and both control (reference) sites since the onset of wastewater discharge from the PLOO (**Table 5.3**). There was also a net change in infaunal abundance between E14 and control site B9. The change in species richness may be due to the increased variability and higher numbers of species at the impact site over time (**Figure 5.3A**). Differences in *Amphiodia* populations reflect a decrease in the number of these ophiuroids collected at E14 and a general increase at the control stations until about 2001 (Figure 5.3E). *Amphiodia urtica* densities at station E14 in 2007 were higher than in 2006 but remain similar to the low densities that have occurred since 1999. While densities of this brittle star have declined in recent years at both control sites, they are more similar to pre-discharge values than densities near the outfall. Differences in the BRI generally are due to increased index values at station E14 since 1994 (Figure 5.3C). These higher BRI values may be explained in part by the lower numbers of *Amphiodia*. The results for total infaunal abundances were more ambiguous (Figure 5.3B, Table 5.3). While the difference in mean abundances between station B9 and the impact site has changed since discharge began, no such pattern is apparent regarding the second

Table 5.3

Results of BACIP t-tests for number of species (SR), infaunal abundance, benthic response index (BRI), and the abundance of several representative taxa around the PLOO (1991–2007). Impact site = near-ZID station E14; Control sites = far-field station E26 or reference station B9. Before impact period = July 1991 to October 1993 (n = 10); After impact period = January 1994 to July 2007 (n = 47). Critical t value = 1.680 for $\alpha = 0.05$ (one-tailed t-tests, df = 55). ns = not significant .

Variable	Control vs Impact	t	p
SR	E26 v E14	-3.152	0.002
	B9 v E14	-3.671	<0.001
Abundance	E26 v E14	-1.415	ns
	B9 v E14	-2.712	0.004
BRI	E26 v E14	-3.775	<0.001
	B9 v E14	-2.239	<0.001
Amphiodia spp	E26 v E14	-7.381	<0.001
	B9 v E14	-5.004	<0.001
Ampelisca spp	E26 v E14	-1.598	ns
	B9 v E14	-0.041	ns
Rhepoxynius spp	E26 v E14	-0.830	ns
	B9 v E14	-0.922	ns

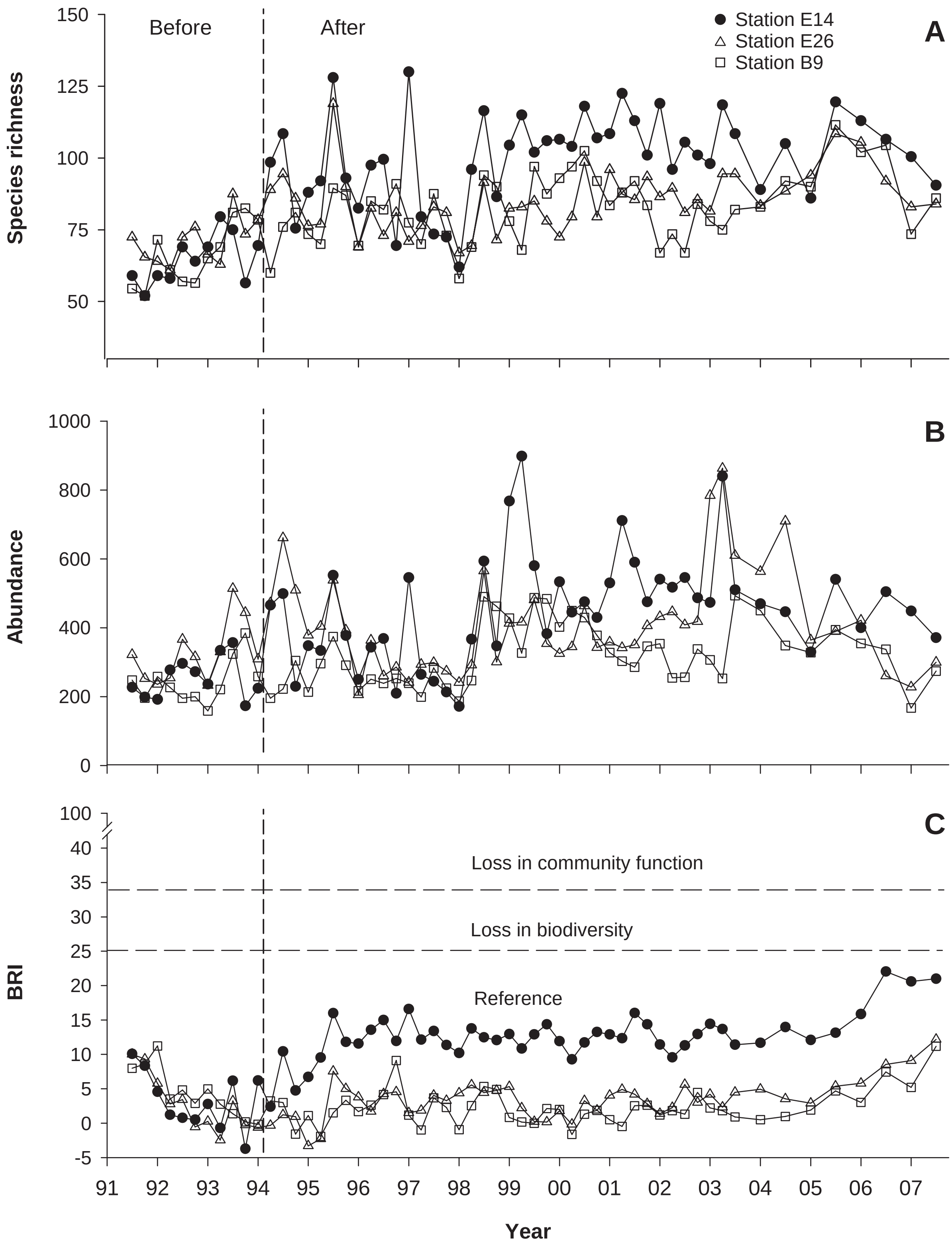

Figure 5.3

Comparison of several parameters at "impact" site (station E14) and "control" sites (stations E26, B9) used in BACIP analyses (see Table 5.3). Data for each station are expressed as means per 0.1 m^2 (n=2 per survey). (A) Number of infaunal species; (B) infaunal abundance; (C) Benthic Response Index (BRI); (D) abundance of *Ampelisca* spp (Amphipoda); (E) abundance of *Amphiodia* spp (Ophiuroidea).

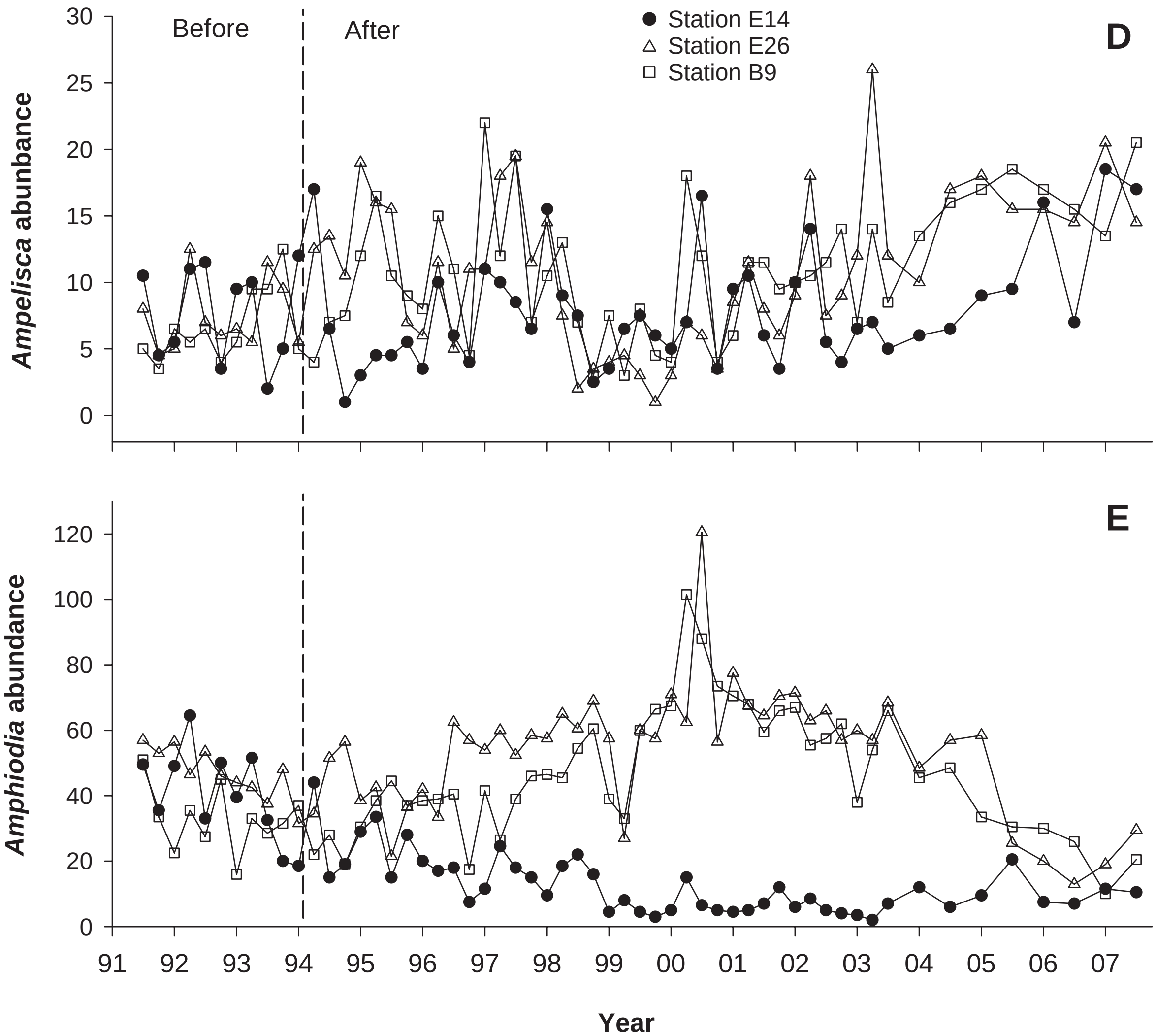

Figure 5.3 *Continued*

control site (E26). Finally, no significant changes in the difference in mean abundances of ampeliscid or phoxocephalid amphipods at the impact and control sites have occurred since discharge began (Figure 5.3D, Table 5.3).

Classification of Benthic Assemblages

Classification analyses discriminated differences between five main benthic assemblages (cluster groups A–E) in the Point Loma region during 2007 **(Figures 5.4, 5.5**). These assemblages differed in terms of species composition, including the specific taxa present and their relative abundances. SIMPER analysis was used to identify species that were characteristic, though not always the most abundant, within each assemblage (Figure 5.4A). The numerically dominant species for each assemblage are listed in **Table 5.4**. Additionally, MDS ordination results confirmed the validity of the major cluster groups (Figure 5.4B).

Cluster group A comprised the assemblage from the January survey of B11, located farthest to the north from the PLOO discharge site. The ophiuroid *Amphiodia urtica* was the dominant species characterizing this assemblage. The next two characteristic species were the bivalve *Adontorhina cyclia* and the cirratulid polychaete *Chaetozone hartmanae*. This assemblage had the lowest mean abundance (246 per 0.1 m^2) compared to the other cluster groups. Species richness averaged 99 taxa per grab. Sediments at this site were mixed with 45% fine particles and with coarse materials

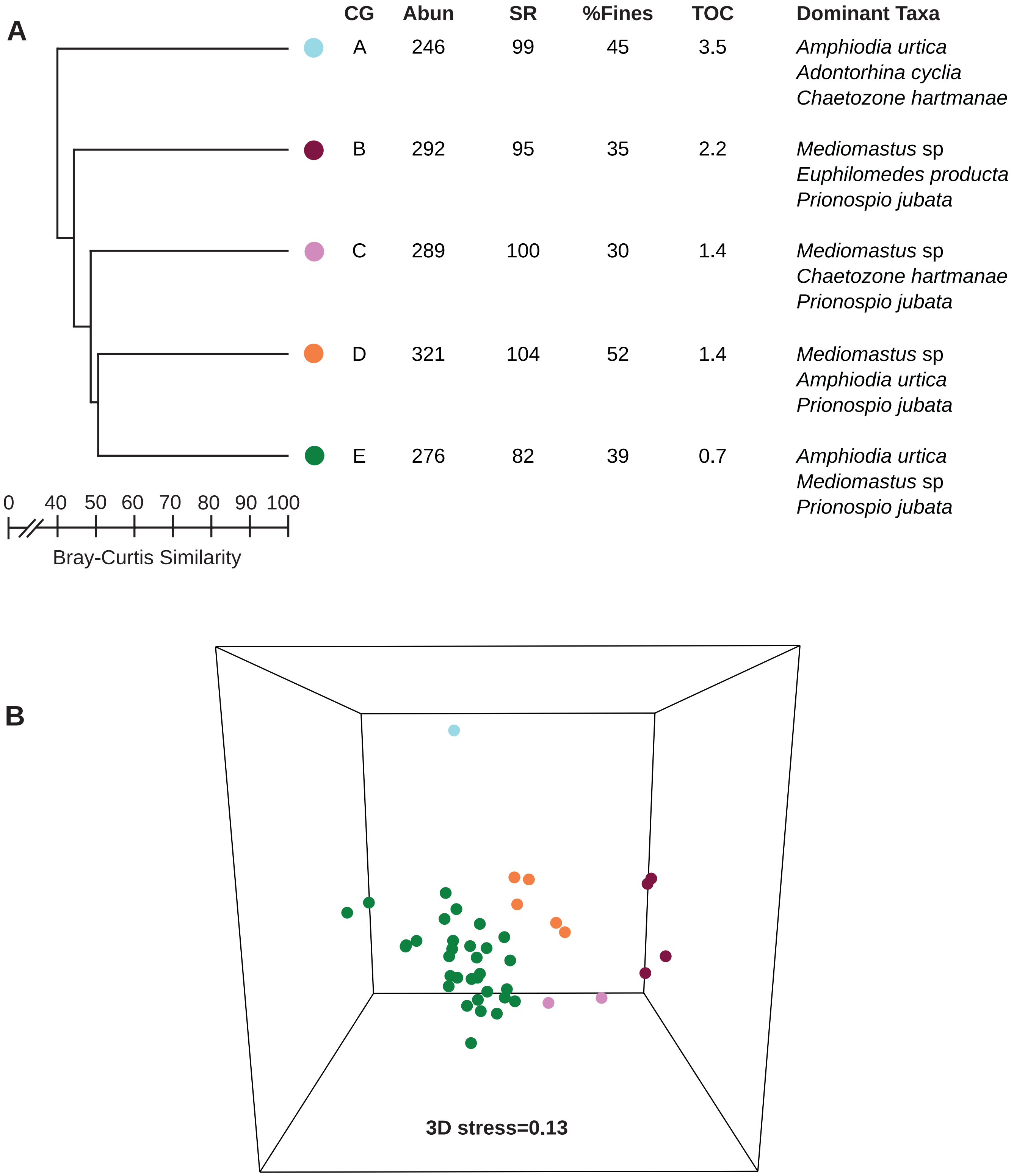

Figure 5.4
(A) Cluster results of the macrofaunal abundance data for the PLOO benthic stations sampled during winter and summer 2007. Data for infaunal abundance (Abun), species richness (SR), percent fines, and total organic carbon (TOC) are expressed as mean values per 0.1-m^2 grab over all stations in each group. (B) MDS ordination based on square-root transformed macrofaunal abundance data for each station/survey entity. Cluster groups superimposed on station/surveys illustrate a clear distinction between faunal assemblages.

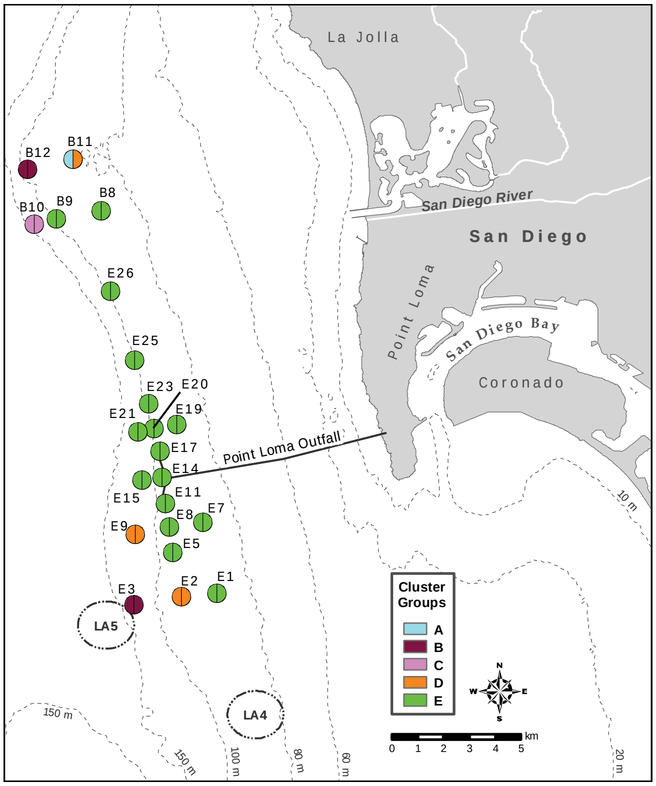

Figure 5.5
Distribution of macrobenthic assemblages off Point Loma delineated by ordination and classification analyses.

including some small rocks and shell hash. Total organic carbon (TOC) concentration was 3.5%, the highest among all cluster groups.

Cluster group B included animals from one northern reference site (station B12) and one site located south of the PLOO (station E3). Dominant species in this assemblage included the capitellid polychaete *Mediomastus* sp, the ostracod *Euphilomedes producta*, and the spionid polychaete *Prionospio jubata*. Species richness was 95 species per 0.1 m^2, while abundance averaged 292 individuals per grab. Sediments associated with this group contained 35% fine particles. The mean TOC value of 2.2% for the sites in this group was the second highest among the cluster groups.

Cluster group C represented animals from northern station B10 located along the 116-m contour. Dominant taxa included *Mediomastus* sp, *Chaetozone hartmanae* and *Prionospio jubata*. This assemblage averaged 289 individuals and 100 species per 0.1 m^2. Sediments at station B10 were mixed, composed of 30% fines with some shell hash and small rocks. TOC levels at stations within this group averaged 1.4%.

Cluster group D included animals collected from three widely dispersed sites. These included assemblages from the July survey of northern station B11 located along the 88-m contour, and both surveys from stations E2 (98 m) and E9 (116 m) located south of the PLOO. The numerically dominant species in this group were *Mediomastus* sp, *Amphiodia urtica*, and *Prionospio jubata*. This assemblage averaged 321 individuals and 104 taxa per 0.1 m^2. The stations associated with this assemblage had the highest percentage of fines (52%), while TOC concentrations averaged 1.4% similar to group C.

Cluster group E represented the most wide-spread assemblage in 2007, comprising animals from 66% of the samples and 16 stations. The dominant species in this group were *Amphiodia urtica*, *Mediomastus* sp, and *Prionospio jubata*. Average abundance for this was group was 276 individuals per 0.1 m^2, which was lower than for most other assemblages. Only cluster group A, which represented samples from only one station during a single survey (station B11) averaged fewer animals. Group E also had the lowest species richness of all groups, averaging just 82 species per grab. The sediments associated with this assemblage were characterized by silty sand with 39% fines. TOC averaged 0.7%, which was the lowest of all groups.

Summary and Conclusions

Benthic communities around the PLOO continue to be dominated by ophiuroid-polychaete based assemblages, with few major changes having occurred since monitoring began (see City of San Diego 1995, 1999, 2007b). Polychaetes and ophiuroids continue to be the most abundant and diverse infauna in the region. Although many of the 2007 assemblages were dominated by similar species, the relative abundance of these species varied among sites. In contrast to 2004 and 2005 but similar to 2006, the oweniid polychaete *Myriochele*

Table 5.4

Summary of the most abundant taxa composing cluster groups A–E from the 2007 surveys of PLOO benthic stations. Data are expressed as mean abundance per sample (no./0.1 m^2) and represent the most abundant taxa in each group. Values for the three most abundant species in each cluster group are in bold, n=number of station/survey entities per cluster group.

Species/Taxa	Higher taxa	Cluster group A (n=1)	B (n=4)	C (n=2)	D (n=5)	E (n=32)
Adontorhina cyclia	Mollusca: Bivalvia	**11.5**	0.3	5.8	5.9	4.3
Ampelisca careyi	Crustacea: Amphipoda	1.5	5.5	4.3	3.2	1.4
Ampelisca pacifica	Crustacea: Amphipoda	3.0	3.0	4.5	7.1	6.0
Amphiodia digitata	Echinodermata: Ophiuroidea	—	5.4	1.3	2.0	0.2
Amphiodia sp	Echinodermata: Ophiuroidea	4.5	2.1	2.0	8.5	9.2
Amphiodia urtica	Echinodermata: Ophiuroidea	**19.0**	1.5	3.0	**22.9**	**23.2**
Aphelochaeta monilaris	Polychaeta: Cirratulidae	—	0.8	10.5	1.2	1.8
Aricidea catherinae	Polychaeta: Paraonidae	—	5.0	8.3	6.8	9.5
Axinopsida serricata	Mollusca: Bivalvia	8.0	0.8	1.8	4.8	7.2
Caecum crebricinctum	Mollusca: Gastropoda	—	7.3	—	—	—
Chaetozone hartmanae	Polychaeta: Cirratulidae	**10.5**	1.9	**13.0**	4.9	6.4
Decamastus gracilis	Polychaeta: Capitellidae	—	6.6	9.0	3.0	4.3
Euphilomedes carcharodonta	Crustacea: Ostracoda	0.5	1.8	2.0	3.1	6.3
Euphilomedes producta	Crustacea: Ostracoda	3.5	**17.3**	9.8	12.2	7.7
Exogone lourei	Polychaeta: Syllidae	1.0	6.8	—	1.0	—
Glycera nana	Polychaeta: Glyceridae	4.5	4.5	2.3	4.3	3.1
Lumbrineris cruzensis	Polychaeta: Lumbrineridae	1.5	2.4	3.3	6.5	4.5
Lumbrineris sp group I	Polychaeta: Lumbrineridae	—	2.3	0.3	5.9	7.6
Mediomastus sp	Polychaeta: Capitellidae	1.0	**32.0**	**27.8**	**27.2**	**24.5**
Monticellina siblina	Polychaeta: Cirratulidae	—	5.8	1.5	0.9	1.3
Parvilucina tenuisculpta	Mollusca: Bivalvia	—	0.4	6.3	0.2	1.5
Pholoides asperus	Polychaeta: Pholoidae	6.0	0.6	0.5	0.6	—
Phoronis sp	Phoronida: Phoronidae	7.0	0.3	0.3	0.9	0.2
Piromis sp A	Polychaeta: Flabelligeridae	5.0	—	0.3	0.4	—
Prionospio dubia	Polychaeta: Spionidae	2.5	5.5	2.3	8.5	2.7
Prionospio jubata	Polychaeta: Spionidae	4.5	**21.4**	**11.8**	**13.2**	**10.9**
Sternaspis fossor	Polychaeta: Sternaspidae	1.5	1.6	7.0	2.1	3.3

striolata was not among the most abundant or widespread invertebrates in the region. Instead, the brittle star *Amphiodia urtica* was the most abundant and widespread taxon. The capitellid polychaete *Mediomastus* sp was the second most widespread benthic invertebrate, being dominant in four of the five main assemblages. Assemblages similar to those off Point Loma have been described for other areas in the Southern California Bight (SCB) by Barnard and Ziesenhenne (1961), Jones (1969), Fauchald and Jones (1979), Thompson et al. (1987, 1992, 1993a), Zmarzly et al. (1994), Diener and Fuller (1995), and Bergen et al. (1998, 2000).

Although variable, benthic communities off Point Loma generally have remained similar from year to year in terms of the number of species, number of individuals, and dominance (e.g., City of San Diego 1995, 1999, 2007b). In addition, values for these parameters in 2007 were similar to those described for other sites throughout the SCB (e.g., Thompson et al. 1993b, Bergen et al. 1998, 2000, 2001, Ranasinghe et al. 2003, 2007). In spite of this overall stability, there has been some increase in the number of species and macrofaunal abundance during the post-discharge period (see City of San Diego 1995, 1999, 2007b).

The increase in species has also occurred near the outfall, which suggests that substantial environmental degradation has not occurred there. In addition, the recent observed decreases in abundance at most stations in 2006 and 2007 were not accompanied by changes in dominance, a pattern inconsistent with predicted pollution effects. Further, benthic communities around the PLOO are not dominated by a few pollution tolerant species. For example, the opportunistic polychaete *Capitella capitata*, which is often associated with degraded soft bottom habitats, continues to occur in relatively low numbers off Point Loma. A total of 136 individual *C. capitata* were collected off Point Loma in 2007, with 129 occurring at several stations located nearest the PLOO discharge site (i.e., E11, E14 and E17). Densities of this polychaete at these three sites averaged 16 individuals per 0.1 m^2. In contrast, populations of *C. capitata* typically exceed densities of 500 individuals per 0.1 m^2 and constitute as much as 85% of the total abundance in polluted sediments (Swartz et al. 1986).

A few changes near the outfall suggest some effects are coincident with anthropogenic activities. BRI values are higher at stations nearest the outfall (E11, E14, E17) than at other sites in the region (see City of San Diego 2007b). In addition, increases in BRI that occurred at station E14 after discharge began may be considered indicative of organic enrichment or some other type of disturbance. However, BRI values at this and all other sites remain characteristic of undisturbed areas (see City of San Diego 1995, 2007b). The increased variability in number of species and infaunal abundance at station E14 since discharge began may be indicative of community destabilization (see Warwick and Clarke 1993, Zmarzly et al. 1994). There has been some change in sediments at E14 since construction of the PLOO (see City of San Diego 2007b). This suggest that changes in community structure near the PLOO could be related to localized physical disturbance associated with the structure of the outfall pipe as well as to organic enrichment associated with the discharge of effluent.

Populations of some indicator taxa revealed changes that correspond to organic enrichment near the outfall. For example, since 1997, there has been a significant change in the difference between ophiuroid (*Amphiodia* spp) populations that occur nearest the outfall (i.e., station E14) and those present at reference sites. This difference is mostly due to a decrease in numbers of ophiuroids near station E14 and a concomitant increase at reference areas during the post-discharge period. However, these differences have decreased over the past three years. Although long term changes in *Amphiodia* populations at E14 may likely be related to organic enrichment, altered sediment composition, or some other factor, abundances for the Point Loma region in general are still within the range of those occurring naturally in the SCB. In addition, natural population fluctuations of these and other resident species (e.g. *Myriochele striolata* and *Proclea* sp A) are common off San Diego (Zmarzly et al. 1994, Diener et al. 1995). Further complicating the picture, stable patterns in populations of pollution sensitive amphipods (i.e., *Ampelisca*, *Rhepoxynius*) and a limited presence of a pollution tolerant species (e.g., *Capitella capitata*) do not offer evidence of significant outfall-related effects.

While it is difficult to detect specific effects of the PLOO on the offshore benthos, it is possible to see some changes occurring nearest the discharge site. Because of the minimal extent of these changes, it has not been possible to determine whether observed effects are due to habitat alteration related to the physical structure of the outfall pipe, organic enrichment, or a combination of factors. Such impacts have spatial and temporal dimensions that vary depending on a range of biological and physical factors. In addition, abundances of soft bottom invertebrates exhibit substantial spatial and temporal variability that may mask the effects of any disturbance event (Morrisey et al. 1992a, 1992b, Otway 1995). The effects associated with the discharge of advanced primary treated and secondary treated sewage may be negligible or difficult to detect in areas subjected to strong currents that facilitate the dispersion of the wastewater plume (see Diener and Fuller 1995). Although some changes in benthic assemblages have appeared near the outfall, assemblages in the Point Loma region are still similar to those observed prior to discharge and to natural indigenous communities characteristic of the southern California continental shelf.

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Chapter 6. Demersal Fishes and Megabenthic Invertebrates

INTRODUCTION

Marine fishes and invertebrates are conspicuous members of continental shelf habitats, and assessment of their communities has become an important focus of ocean monitoring programs throughout the world. Assemblages of bottom dwelling (demersal) fishes and relatively large (megabenthic), mobile invertebrates that live on the surface of the seafloor have been sampled extensively for more than 30 years on the mainland shelf of the Southern California Bight (SCB), primarily by programs associated with municipal wastewater and power plant discharges (Cross and Allen 1993). More than 100 species of demersal fish inhabit the SCB, while the megabenthic invertebrate fauna consists of more than 200 species (Allen 1982, Allen et al. 1998, 2002, 2007). For the region surrounding the Point Loma Ocean Outfall (PLOO), the most common trawl-caught fishes include Pacific sanddab, longfin sanddab, Dover sole, hornyhead turbot, California tonguefish, plainfin midshipman, and yellowchin sculpin. Common trawl-caught invertebrates include relatively large taxa such as the sea urchins *Lytechinus pictus* and *Allocentrotus fragilis*, and the sea stars *Luidia foliata* and *Astropecten verrilli*.

Demersal fish and megabenthic invertebrate communities are inherently variable and may be influenced by both anthropogenic and natural factors. These organisms live in close proximity to the seafloor and are therefore exposed to contaminants of anthropogenic origin that may accumulate in the sediments via both point and non-point sources (e.g., discharges from ocean outfalls and storm drains, surface runoff from watersheds, outflows from rivers and bays, disposal of dredge materials). Natural factors that may affect assemblages of these fish and invertebrates include prey availability (Cross et al. 1985), bottom relief and sediment structure (Helvey and Smith 1985), and changes in water temperatures associated with large scale oceanographic events such as El Niño/La Niña oscillations (Karinen et al. 1985). These factors can affect migration patterns of adult fish or the recruitment of juveniles into an area (Murawski 1993). Population fluctuations that affect species diversity and abundance may also be due to the mobile nature of many species (e.g., schools of fish or aggregations of urchins).

The City of San Diego has been conducting trawl surveys in the area surround the present discharge site for the Point Loma Ocean Outfall (PLOO) since 1991. These surveys are designed to monitor the effects of wastewater discharge on the local marine biota by assessing the structure and stability of trawl-caught fish and invertebrate communities. This chapter presents analyses and interpretations of the demersal fish and megabenthic invertebrate data collected during 2007. A long-term analysis of changes in these communities from 1991 through 2007 is also presented

MATERIALS AND METHODS

Field Sampling

Trawl surveys were conducted at six fixed monitoring sites in the Point Loma region during 2007 (**Figure 6.1**). These surveys were performed during winter (February) and summer (July) for a total of 12 trawls during the year. The six trawl stations, designated SD7, SD8, SD10, SD12, SD13 and SD14, are located along the 100-m isobath, and encompass an area ranging from about 8 km north to 9 km south of the PLOO. A single trawl was performed at each station during both surveys using a 7.6-m Marinovich otter trawl fitted with a 1.3-cm cod-end mesh net. The net was towed for 10 minutes bottom time at a speed of about 2.5 knots along a predetermined heading.

Trawl catches were brought on board for sorting and inspection. All fish and invertebrates were identified to species or to the lowest taxon possible. If an animal could not be identified in the field, it was returned

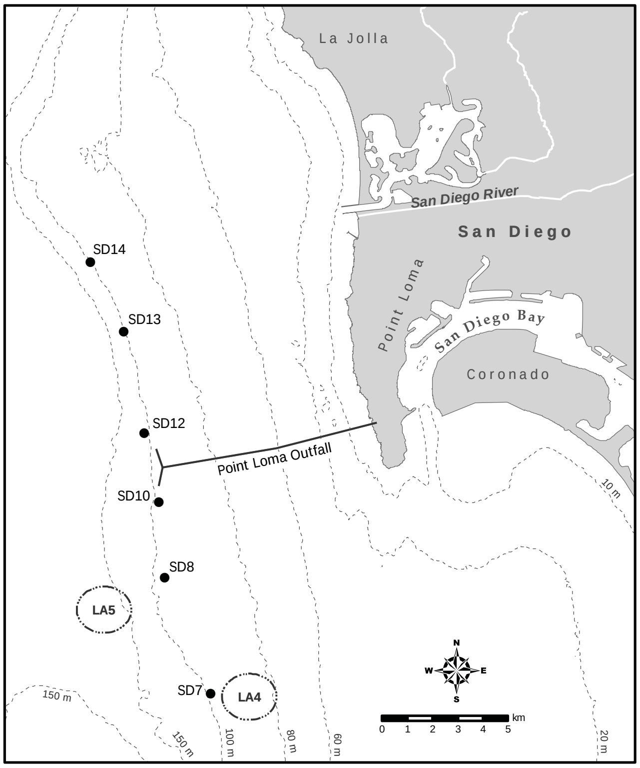

Figure 6.1
Otter trawl station locations, Point Loma Ocean Outfall Monitoring Program.

to the laboratory for further identification. For fishes, the total number of individuals and total biomass (wet weight, kg) were recorded for each species. Additionally, each individual fish was inspected for external parasites or physical anomalies (e.g., tumors, fin erosion, discoloration) and measured to the nearest centimeter size class (standard lengths). For invertebrates, the total number of individuals per species was recorded.

Data Analyses

Populations of each fish and invertebrate species were summarized as percent abundance, frequency of occurrence, mean abundance per haul, and mean abundance per occurrence. In addition, species richness (number of species), total abundance, and Shannon diversity index (H') were calculated for both fish and invertebrate assemblages at each station. Total biomass was also calculated for each fish species by station.

Multivariate analyses were performed on 17 years of demersal fish data from the above six trawl stations (i.e., 1991–2007). The data set was limited to results from just the July surveys conducted each year in order to eliminate seasonal influences. PRIMER software was used to examine spatio-temporal patterns in the overall similarity of fish assemblages (see Clarke 1993, Warwick 1993). These analyses included classification (cluster analysis) by hierarchical agglomerative clustering with group-average linking, and ordination by non-metric multidimensional scaling (MDS). The fish abundance data were square root transformed, and the Bray-Curtis measure of similarity was used as the basis for classification. Because species composition was sparse at some stations, a dummy species with a value of one was added to all samples prior to computing similarities (see Clarke and Gorley 2006).

Results and Discussion

Fish Community

Thirty-eight species of fish were collected in the area surrounding the PLOO in 2007 along with some unidentified (juvenile) rockfish and flatfish (**Table 6.1**). The total catch for the year was 2454 individuals, representing an average of about 204 fish per trawl. Pacific sanddabs were the dominant fish captured, occurring in every haul and accounting for 45% of the total number of fishes collected during the year. Halfbanded rockfish, longspine combfish, Dover sole, English sole, shortspine combfish, pink seaperch, plainfin midshipman, hornyhead turbot, California tonguefish, and bigmouth sole were also collected frequently (≥75% of the trawls). Pacific sanddabs averaged 92 fish per occurrence, while all other species averaged 20 or less with each contributing to no more than 10% of the total catch. The majority of species tended to be relatively small fish with an average length <20 cm (see **Appendix C.1**). Larger species such as sharks, skates and rays were relatively rare in the trawls. These included the California skate, spotted ratfish, and Pacific electric ray.

Species richness, diversity (H'), abundance and biomass values were all relatively low for trawl-caught fishes off Point Loma during 2007 (**Table 6.2**). No more than 24 species occurred in any one haul, and

Table 6.1

Demersal fish species collected in 12 trawls in the PLOO region during 2007. PA=percent abundance; FO=frequency of occurrence; MAO=mean abundance per occurrence; MAH=mean abundance per haul.

Species	PA	FO	MAO	MAH	Species	PA	FO	MAO	MAH
Pacific sanddab	45	100	92	92	Blackbelly eelpout	<1	25	4	1
Halfbanded rockfish	10	100	20	20	Greenblotched rockfish	<1	25	2	1
Longspine combfish	8	92	19	17	Roughback sculpin	<1	25	2	1
Dover sole	8	100	16	16	Flag rockfish	<1	25	1	<1
English sole	5	92	10	10	Spotted ratfish	<1	25	1	<1
Shortspine combfish	4	92	9	8	White croaker	<1	17	3	1
Pink seaperch	3	92	8	7	California lizardfish	<1	17	3	<1
Plainfin midshipman	3	92	7	7	California skate	<1	17	2	<1
Yellowchin sculpin	2	58	8	5	Blacktip poacher	<1	17	2	<1
Hornyhead turbot	2	92	5	4	Pacific hake	<1	17	1	<1
California tonguefish	2	75	4	3	Bluespotted poacher	<1	8	1	<1
Slender sole	1	50	5	2	Calico rockfish	<1	8	1	<1
Bigmouth sole	1	92	2	2	Chilipepper rockfish	<1	8	1	<1
California scorpionfish	1	42	4	2	Fringed sculpin	<1	8	1	<1
Spotfin sculpin	1	42	3	1	Greenspotted rockfish	<1	8	1	<1
Pygmy poacher	1	42	3	1	Pacific argentine	<1	8	1	<1
Greenstriped rockfish	<1	58	2	1	Pacific electric ray	<1	8	1	<1
Stripetail rockfish	<1	42	2	1	Pink rockfish	<1	8	1	<1
Spotted cuskeel	<1	33	3	1	Squarespot rockfish	<1	8	1	<1
Unidentified rockfish	<1	33	1	<1	Unidentified flatfish	<1	8	1	<1

Table 6.2

Summary of demersal fish community parameters for PLOO stations sampled during 2007. Data are included for species richness (number of species), abundance (number of individuals), diversity (H'), and biomass (kg, wet weight).

			Annual					Annual	
Station	Winter	Summer	Mean	SD	Station	Winter	Summer	Mean	SD
Species Richness					*Abundance*				
SD7	19	19	19	0	SD7	268	118	193	106
SD8	24	21	23	2	SD8	219	208	214	8
SD10	17	15	16	1	SD10	196	257	227	43
SD12	14	14	14	0	SD12	250	208	229	30
SD13	15	14	15	1	SD13	144	161	153	12
SD14	14	21	18	5	SD14	180	250	215	49
Survey Mean	17	17			Survey Mean	210	200		
Survey SD	4	3			Survey SD	46	53		
Diversity					*Biomass*				
SD7	2.08	1.28	1.68	0.57	SD7	8.9	3.4	6.2	3.9
SD8	2.03	1.73	1.88	0.21	SD8	8.1	5.7	6.9	1.7
SD10	1.95	1.79	1.87	0.11	SD10	9.0	8.4	8.7	0.4
SD12	1.98	1.92	1.95	0.04	SD12	10.5	5.4	8.0	3.6
SD13	2.06	1.68	1.87	0.27	SD13	5.4	4.3	4.9	0.8
SD14	1.87	1.62	1.75	0.18	SD14	5.0	12.1	8.6	5.0
Survey Mean	2.00	1.67			Survey Mean	7.8	6.6		
Survey SD	0.08	0.22			Survey SD	2.2	3.2		

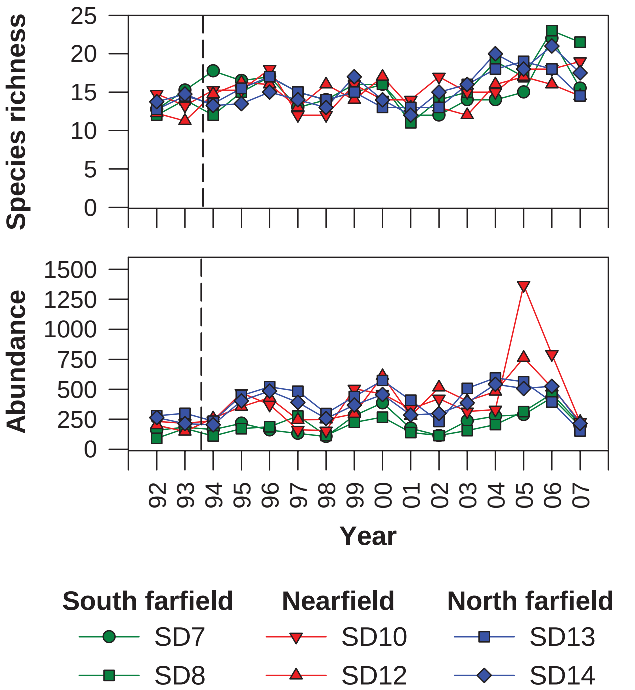

Figure 6.2
Species richness (number of species) and abundance (number of individuals) of demersal fish collected at each PLOO trawl station between 1992 and 2007. Data are annual means (n=4 for 1992–2002; n=3 in 2003; n=2 for 2004–2007). Dotted line represents initiation of wastewater discharge in November 1993.

H' values were less than 2.1 for all assemblages. Total abundance ranged from 118 to 268 fishes per haul, which tended to co-vary with Pacific sanddab populations that ranged between 23–152 fish per catch (**Appendix C.2**). Biomass ranged from 3.4 to 12.1 kg per haul, with higher values coincident either with greater numbers of fishes or the large size of individual fish or fishes. For example, the highest biomass of 12.1 kg occurred for a trawl from station SD14 during the July trawl survey when 9 kg of Pacific sanddabs were captured (**Appendix C.3**).

Large fluctuations in populations of a few dominant species have been the primary factor contributing to the high variation in fish community structure off Point Loma since 1992 (**Figure 6.2**, **Figure 6.3**). For example, species richness has consistently averaged between about 10–23 species per station, while mean abundances have varied between 93 and 1368 individuals. These fluctuations in abundance have been greatest at stations SD10, SD12, SD13 and SD14 and generally reflect differences in

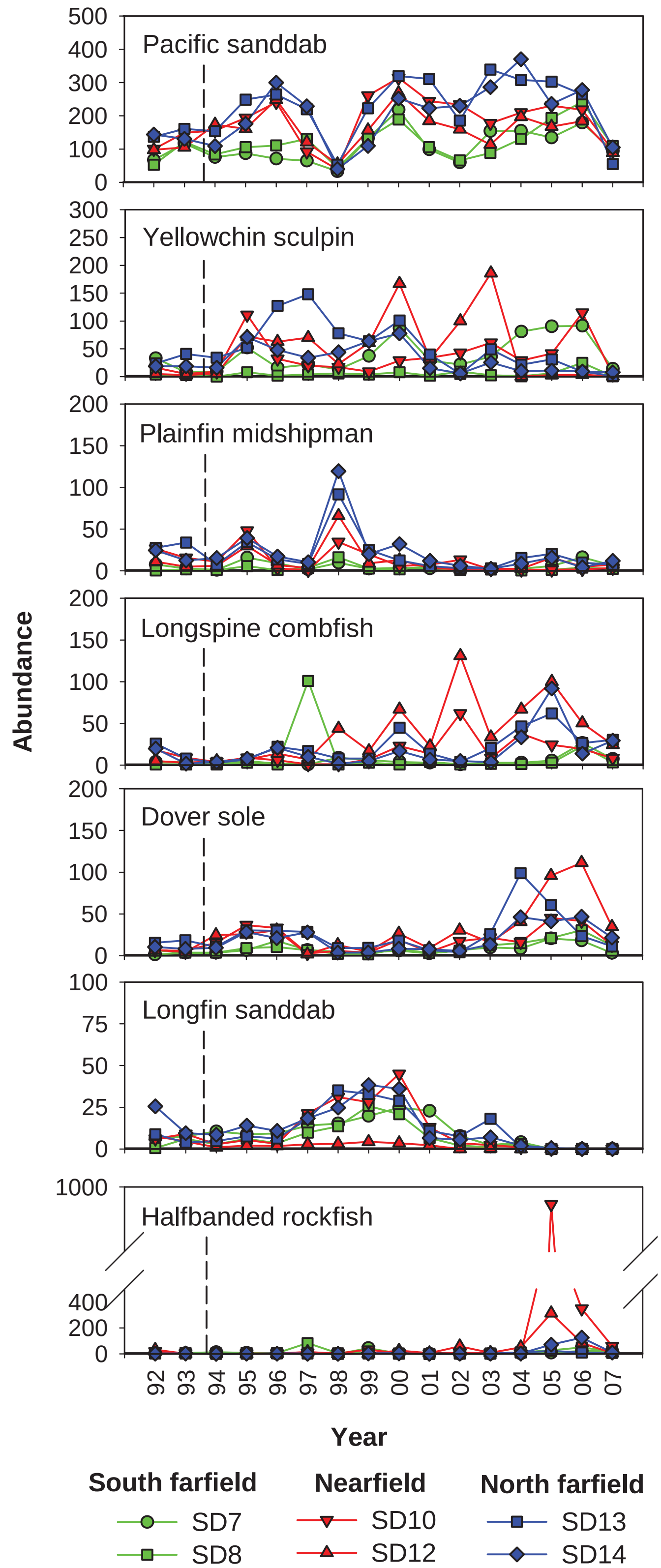

Figure 6.3
Abundance of the seven most abundant fish species collected in the PLOO region from 1992 through 2007. Data are annual means (n=4 for 1992–2002; n=3 in 2003; n=2 for 2004–2007). Dotted line represents initiation of wastewater discharge in November 1993.

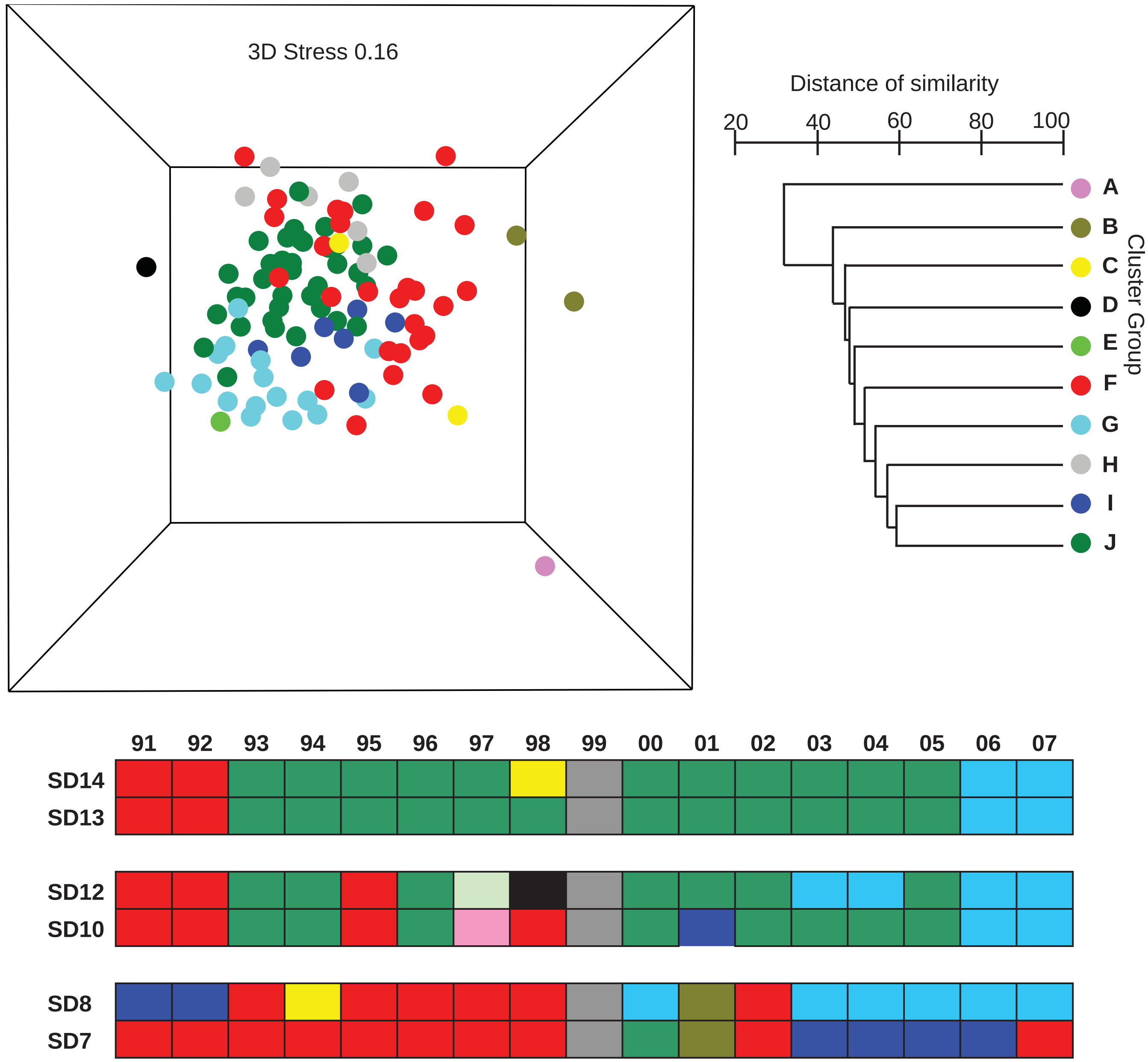

Figure 6.4
Results of classification analysis of demersal fish assemblages collected at PLOO stations SD7–SD14 between 1991 and 2007 (July surveys only). Data are presented as (A) MDS ordination, (B) a dendrogram of major cluster groups and (C) a matrix showing distribution of cluster groups over time.

populations of several dominant species. For example, the overall low abundance in 2007 was due to significantly fewer numbers of Pacific sanddabs, yellowchin sculpin, longspine combfish, Dover sole, and halfbanded rockfish captured during the year. Moreover, patterns of change in the dominant species over time were generally similar among stations closest to the outfall and those at the northern sites. None of the observed changes appear to be associated with wastewater discharge. For example, no changes that have occurred at the trawl stations nearest the outfall were coincident with the onset of discharge in late 1993.

Ordination and classification analyses of fish abundance data from 1991 through 2007 distinguished between 10 major cluster groups or assemblages (cluster groups A–J; see **Figure 6.4**). These results indicate that the demersal fish community off Point Loma remains dominated by

Table 6.3

Description of cluster groups A–J defined in Figure 6.4. Data include number of hauls, mean species richness, mean total abundance, and mean abundance of the five most abundant species for each station group.

	Cluster Group									
	A	B	C	D	E	F	G	H	I	J
Number of hauls	1	2	2	1	1	27	16	6	7	39
Mean species richness	7	11	11	16	19	13	17	16	15	15
Mean abundance	44	68	74	261	231	152	326	362	223	378
Species	**Mean Abundance**									
Greenspotted rockfish	1				1	<1		1		<1
Gulf sanddab	1		1	5				5		
Longfin sanddab	1	3	1			5	1	25		5
Pink seaperch	1	1	2	4	1	1	3	2	3	5
Spotfin sculpin	1		2			2	4			
Halfbanded rockfish	16				60	2	68	5	6	7
Pacific sanddab	23	46	48	75	110	88	164	201	149	254
Bigmouth sole		3			1	1	1	1	<1	1
California tonguefish		3			1	3	3	4	1	1
Dover sole		1	6	36	1	11	28	4	16	34
Greenblotched rockfish		1	2		8	1	1	1	2	1
Longspine combfish		3	2	7	2	1	10	4	4	17
Plainfin midshipman			2	116	4	16	4	13	3	9
Shortspine combfish					3	2	12	1	7	2
Squarespot rockfish		1			23					
Stripetail rockfish			8	1	5	8	2	61	<1	8
Vermilion rockfish					6					
Yellowchin sculpin		5				3	1	21	20	15

Pacific sanddabs, with differences in the relative abundance of this or other commons species discriminating between the different cluster groups (see **Table 6.3**). The overall distribution of assemblages in 2007 was generally similar to that observed in 2006, with both being fairly distinct compared to previous years. There do not appear to be any spatial or temporal patterns that can be attributed to the outfall or the onset of wastewater discharge. Instead, most differences in local fish assemblages appear to be more closely related to large-scale oceanographic events (e.g., El Niño conditions in 1998) or proximity to other potential contaminant sources. For example, fish assemblages at stations SD7 and SD8 located south of the outfall and not far from the LA-4 and LA-5 disposal sites, respectively, often grouped apart from the remaining trawls stations. The composition and characteristics of each cluster group are summarized above (Table 6.3).

Cluster groups A-E comprised five unique assemblages formed by one or two station/survey entities (i.e., trawl catch), accounting for <7% of the total number of trawls. Most of these groups were dominated by Pacific sanddabs, but were unique in terms of lower total abundance and species richness values, and/or relatively high numbers of less common species (e.g, midshipman, rockfish). Cluster group A represented the assemblage from station SD10 sampled in 1997; this assemblage was characterized by the fewest fish (species and abundance) of all hauls (i.e., 44 fishes representing seven species). Cluster groups B and C each consisted of assemblages from only two trawls; group B represented stations SD7 and SD8 sampled in 2001, while group C was comprised of trawls from station SD8 in 1994 and station SD14 in 1998. These two assemblages were characterized by slightly more species than cluster group A (i.e., 11 species), and both also had low total abundances as well as relatively low numbers of Pacific sanddabs. Cluster group D represented the assemblage from station SD12 sampled in 1998; this assemblage was unique because it was dominated by a large population of plainfin midshipman. The second and third most abundant species comprising group D were Pacific sanddabs and Dover sole. Cluster group E represented the assemblage from station SD12 sampled in 1997; this assemblage had the highest number of species overall, and in addition to Pacific sanddabs was characterized by relatively high numbers of halfbanded and squarespot rockfish.

Cluster group F consisted of assemblages from 27 trawls, all but three of which occurred between 1991 and 1998. These included most surveys at stations SD7 and SD8, as well as stations SD10–SD14 sampled during the relatively warm water years of 1991–1992. Overall, this group was characterized by moderate numbers of species and fishes. The dominant species in this group was the Pacific sanddab, which averaged about 88 fish/haul, while plainfin midshipman (~16 fish/haul) and Dover sole (~11 fish/haul) were the next two most abundant species.

Cluster group G was represented the assemblages from about 16% of all trawls. These occurred at stations SD12 in 2003 and 2004, SD8 during 2000 and 2003–2007, and all stations except SD7 during 2006 and 2007. Group G was characterized by the second highest species richness (~17 species/haul), the third highest averages for total abundance (~362 fish/haul) and numbers of Pacific sanddabs (164 fish/haul). The next two most abundant species that characterized this group were halfbanded rockfish (68 fish/haul) and Dover sole (28 fish/haul).

Cluster group H comprised assemblages across all six stations sampled in 1999. This group was characterized by the second highest number of Pacific sanddabs (201 fish/haul), and in contrast to most other groups, relatively higher numbers of stripetail rockfish (61 fish/haul), longfin sanddabs (25 fish/haul), and yellowchin sculpin (21 fish/haual). These three species may have been more prevalent in the region following the warm water conditions associated with the 1998 El Niño.

Cluster group I consisted primarily of assemblages sampled at southern stations SD7 from 2003 to 2006 and SD8 during 1991–1992, as well as from station SD10 in 2001. The group I assemblages were similar to those represented by group G in terms of moderate numbers of species, total abundance, and numbers of Pacific sanddabs, but with fewer numbers of halfbanded rockfish, shortspine combfish, longspine combfish and Dover sole.

Cluster group J comprised assemblages from about 38% of all trawls, most of which were sampled at stations around or north of the PLOO between 1993 and 2005 (i.e., stations SD10–SD14). The main exceptions occurred during and after the 1998 El Niño (i.e., 1998–1999). Group J was characterized by the highest average total abundance, as well the highest number of Pacific sanddabs (254 fish/haul) on average for all cluster groups. The three next most abundant species characterizing this group were Dover sole (34 fish/haul), longspine combfish (17 fish/haul), and yellowchin sculpin (15 fish/haul). Whereas the species characteristic of the group F and H assemblages may have been associated with the warm waters, the high numbers of Pacific sanddabs, Dover sole and combfish characteristic of cluster group J are likely indicative of colder waters that were persistent during the these non-El Niño years.

Physical Abnormalities and Parasitism

Demersal fish populations appeared healthy in the PLOO region during 2007. There were no incidences of fin rot, discoloration, skin lesions, tumors or any other indicators of disease among fishes collected during the year. A single Pacific sanddab collected at station SD14 was found to have a physical deformity; its tail was bent upwards towards its dorsal fin at the caudal peduncle. Evidence of parasitism was also very low for trawl-caught fishes in the region. The copepod eye parasite *Phrixocephalus cincinnatus* occurred on less than 1% of the Pacific sanddabs collected and was present at all stations during all surveys. In addition, the ectoparasitic isopod *Elthusa vulgaris* was observed loose in some trawls. This cymothoid

Table 6.4

Species of megabenthic invertebrates collected in 12 trawls in the PLOO region during 2007. PA=percent abundance; FO=frequency of occurrence; MAO=mean abundance per occurrence; MAH=mean abundance per haul.

Species	PA	FO	MAO	MAH	Species	PA	FO	MAO	MAH
Lytechinus pictus	92	92	1957	1794	*Suberites* sp	<1	25	1	<1
Acanthoptilum sp	4	75	108	81	*Philine alba*	<1	17	2	<1
Allocentrotus fragilis	2	83	53	44	*Podochela lobifrons*	<1	17	2	<1
Luidia foliolata	<1	92	7	6	Porifera	<1	8	3	<1
Parastichopus californicus	<1	83	5	4	*Acanthodoris brunnea*	<1	8	2	<1
Astropecten verrilli	<1	83	4	3	*Neocrangon zacae*	<1	8	2	<1
Spatangus californicus	<1	75	3	3	*Antiplanes catalinae*	<1	8	1	<1
Ophiura luetkenii	<1	67	4	2	*Elthusa vulgaris*	<1	8	1	<1
Sicyonia ingentis	<1	50	4	2	*Euspira draconis*	<1	8	1	<1
Ophiothrix spiculata	<1	25	4	1	*Fusinus barbarensis*	<1	8	1	<1
Luidia armata	<1	25	4	1	*Halocynthia igaboja*	<1	8	1	<1
Octopus rubescens	<1	50	1	1	*Luidia* sp	<1	8	1	<1
Thesea sp B	<1	42	1	1	*Ondontaster crassus*	<1	8	1	<1
Platymera gaudichaudii	<1	42	1	<1	*Paguristes bakeri*	<1	8	1	<1
Luidia asthenosoma	<1	25	2	<1	*Paguristes turgidus*	<1	8	1	<1
Armina californica	<1	17	3	<1	*Paguristes ulreyi*	<1	8	1	<1
Metridium farcimen	<1	17	3	<1	*Platydoris macfarlandi*	<1	8	1	<1
Neosimnia barbarensis	<1	17	3	<1	*Rossia pacifica*	<1	8	1	<1
Pleurobranchaea californica	<1	33	1	<1	*Schmittius politus*	<1	8	1	<1
Florometra serratissima	<1	25	1	<1	*Stylatula elongata*	<1	8	1	<1
Calliostoma turbinum	<1	17	2	<1					

isopod often becomes detached from its host during the sorting of the trawl catch, and therefore it is unknown which fishes were actually parasitized. Although *E. vulgaris* is known to occur on various species of fish in southern California waters, it is especially common on sanddabs and California lizardfish, where it may reach infestation rates of 3% and 80%, respectively (Brusca 1978, 1981).

Invertebrate Community

A total of 23,379 megabenthic invertebrates (~1948 per trawl), representing 40 taxa, were collected during 2007 (**Table 6.4**, **Appendix C.4**). The white sea urchin *Lytechinus pictus* was the most abundant and most frequently captured species. It was present in 92% of the trawls and accounted for 92% of the total invertebrate catch. Other common species that occurred in more than half of the hauls included the sea urchin *Allocentrotus fragilis*, the sea pen *Acanthoptilum* sp, the sea stars *Astropecten verrilli* and *Luidia foliolata*, the brittle star *Ophiura luetkenii,* the sea cucumber *Parastichopus californicus*, and the heart urchin *Spatangus californicus*.

Megabenthic invertebrate community structure varied among stations and between surveys during the year (**Table 6.5**). Species richness ranged from 7 to 18 species per haul, diversity (H') values ranged from 0.06 to 1.13 per haul, and total abundance ranged from 124 to 4033 individuals per haul. Total abundance co-varied with *L. pictus* populations (**Appendix C.5**). For example, stations SD13 and SD14 had much lower abundances (≤964) than the other four stations due to relatively small catches of *L. pictus* (≤925). Diversity values were extremely low (≤1.13) for the entire area due to the numerical dominance of this sea urchin. Dominance of *L. pictus* is typical for these types of habitats throughout the SCB (e.g., Allen et al. 1998).

Invertebrate species richness and abundance have varied over time (**Figure 6.5**). For example, species richness has averaged from 5 to 20 species per year since 1992, although patterns of change have

Table 6.5

Summary of megabenthic invertebrate community parameters for PLOO stations sampled during 2007. Data are included for species richness (number of species), abundance (number of individuals), and diversity (H').

Station	Winter	Summer	Annual Mean	Annual SD
Species Richness				
SD7	12	13	13	1
SD8	18	9	14	6
SD10	10	16	13	4
SD12	10	17	14	5
SD13	9	13	11	3
SD14	7	14	11	5
Survey Mean	11	14		
Survey SD	4	3		
Abundance				
SD7	2417	3225	2821	571
SD8	2905	2462	2684	313
SD10	2338	3175	2757	592
SD12	4033	294	2164	2644
SD13	964	797	881	118
SD14	124	645	385	368
Survey Mean	2130	1766		
Survey SD	1395	1339		
Diversity				
SD7	0.06	0.10	0.08	0.03
SD8	0.14	0.18	0.16	0.03
SD10	0.11	0.11	0.11	0.00
SD12	0.48	0.91	0.70	0.30
SD13	0.24	0.93	0.59	0.49
SD14	1.00	1.13	1.07	0.09
Survey Mean	0.34	0.56		
Survey SD	0.36	0.48		

been similar among stations. In contrast, changes in abundance have differed greatly among the trawl stations. The average annual invertebrate catches have been consistently low at stations SD13 and SD14, while the remaining stations have demonstrated large fluctuations in abundance. These fluctuations typically reflect changes in *L. pictus* populations, as well as populations of the sea urchin *Allocentrotus fragilis*, and to a lesser degree, the sea pen *Acanthoptilum* sp (**Figure 6.6**). Additionally, abundances of these three taxa are typically much lower at the two northern sites, which likely reflect

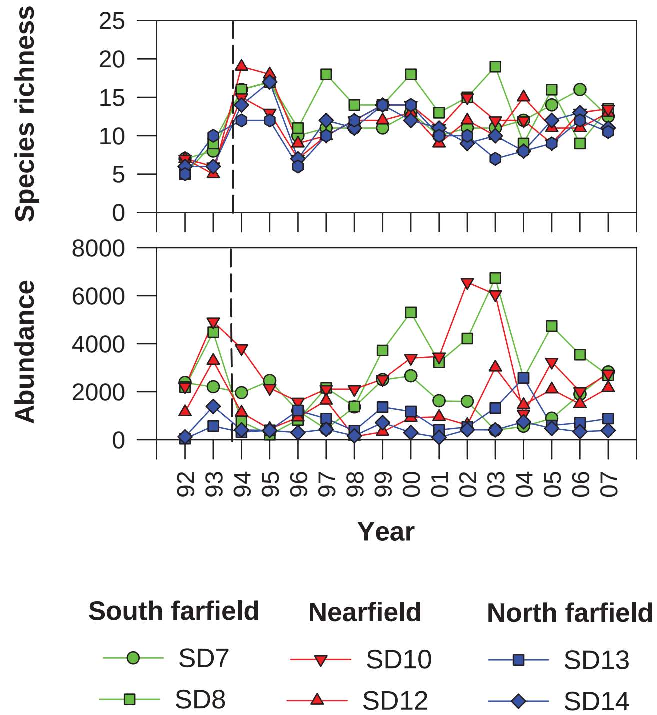

Figure 6.5

Species richness (number of species) and abundance (number of individuals) of megabenthic invertebrates collected at each station between 1992 and 2007. Data are annual means (n=4 for 1992–2002; n=3 in 2003; n=2 for 2004–2007). Dotted line represents initiation of wastewater discharge in November 1993.

differences in sediment composition (e.g., fine sands vs. mixed coarse/fine sediments, see Chapter 4). None of the observed variability in the invertebrate community could be attributed to the discharge of wastewater from the PLOO.

Summary and Conclusions

As in previous years, Pacific sanddabs continued to dominate fish assemblages surrounding the Point Loma Ocean Outfall during 2007. These fish were present in relatively high numbers at all stations. Other characteristic, but less abundant species, included halfbanded rockfish, longspine combfish, Dover sole, English sole, shortspine combfish, pink seaperch, plainfin midshipman, hornyhead turbot, California tonguefish, and bigmouth sole. Although the composition and structure of the fish assemblages varied among stations, most differences were due to fluctuations in Pacific sanddab populations.

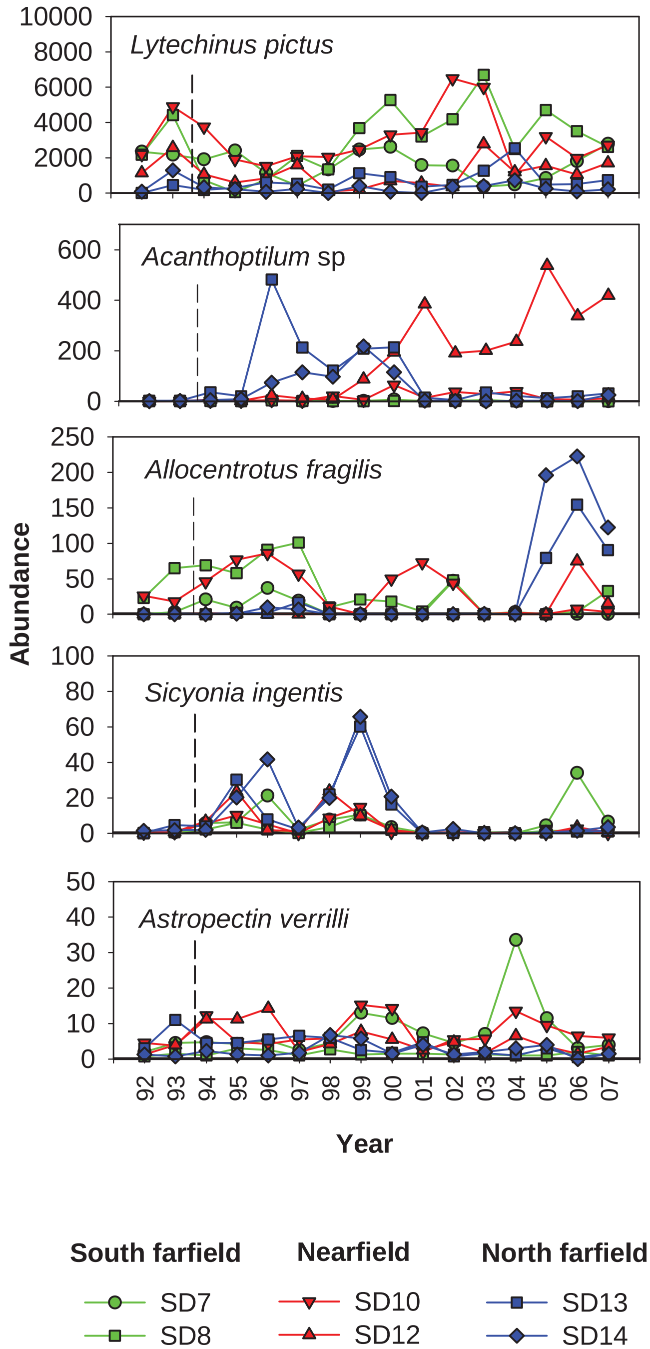

Figure 6.6
Abundance (number of individuals) of the four most abundant megabenthic species collected in the PLOO region from 1992 through 2007. Data are annual means (n=4 for 1992–2002; n=3 in 2003; n=2 for 2004–2007). Dotted line represents initiation of wastewater discharge in November 1993.

Assemblages of megabenthic invertebrates were also dominated by a single prominent species, the white sea urchin *Lytechinus pictus*. Other common species included the sea urchin *Allocentrotus fragilis*, the sea pen *Acanthoptilum* sp, the sea stars *Astropecten verrilli* and *Luidia foliolata*, the brittle star *Ophiura luetkenii*, the sea cucumber *Parastichopus californicus*, and the heart urchin *Spatangus californicus*. Although megabenthic community structure varied between sites, these assemblages were generally characterized by low species richness and diversity. Abundance was proportional to the number of *L. pictus* collected in each haul.

Overall, results of the 2007 trawl surveys provide no evidence that the discharge of wastewater from the Point Loma Ocean Outfall has affected bottom-dwelling fish or megabenthic invertebrate communities in the region. Although highly variable, patterns in the abundance and distribution of species were similar at stations located near the outfall and further away. Changes that have occurred over time in these communities appear to be mostly due to natural factors such as differences in water temperature associated with large scale oceanographic events (El Niño), sediment conditions, and the mobile nature of many species. Finally, the general absence of disease or physical abnormalities suggests that populations of local fishes continue to be healthy off Point Loma.

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Chapter 7: Bioaccumulation of Contaminants in Fish Tissues

INTRODUCTION

Bottom dwelling (i.e., demersal) fishes are collected as part of the Point Loma Ocean Outfall (PLOO) monitoring program to assess the accumulation of contaminants in their tissues. The bioaccumulation of contaminants in a fish occurs through biological uptake and retention of chemical contaminants derived from various exposure pathways (Tetra Tech 1985). Exposure routes for demersal fishes include the uptake of dissolved chemical constituents from the water and the ingestion and assimilation of pollutants from food sources. Because of their proximity to benthic sediments, these fish can also accumulate contaminants by ingesting suspended particulate matter or sediment particles that contain pollutants. For this reason, contaminant levels in the tissues of demersal fish are often related to that found in the environment (Schiff and Allen 1997), thus making these types of assessments useful in biomonitoring programs.

The bioaccumulation portion of the PLOO monitoring program consists of two components: (1) liver tissues are analyzed for trawl-caught fishes; (2) muscle tissues are analyzed for fishes collected by hook and line (rig fishing). Species of fish collected from trawls are considered representative of the general demersal fish community, and certain species are targeted based on their ecological significance (i.e., prevalence in the community). Chemical analysis of liver tissues is important because this is the organ where contaminants typically concentrate (i.e., bioaccumulate). In contrast, fishes targeted for rig fishing represent species characteristic of a typical sport fisher's catch, and are therefore considered of recreational and commercial importance. Muscle tissue is analyzed from these fishes because it is the tissue most often consumed by humans, and therefore the results may have public health implications.

All liver and muscle samples were analyzed for contaminants as specified in the NPDES discharge permit that governs the PLOO monitoring program. Most of these contaminants are also sampled for the National Oceanic and Atmospheric Administration (NOAA) National Status and Trends Program. NOAA initiated this program to detect changes in the environmental quality of the nation's estuarine and coastal waters by tracking contaminants thought to be of environmental concern (Lauenstein and Cantillo 1993). This chapter presents the results of all tissue analyses that were performed on fish collected in the PLOO region during 2007.

MATERIALS AND METHODS

Field Collection

Pacific sanddabs (*Citharichthys sordidus*) and English sole (*Parophrys vetulus*) were collected from four trawling zones, while several species of rockfish (*Sebastes* spp) were collected at the two rig fishing stations in October 2007 (**Table 7.1, Figure 7.1**). Rockfish species included copper rockfish (*S. caurinus*), greenblotched rockfish (*S. rosenblatti*), and vermilion rockfish (*S. miniatus*). Mixed rockfish samples may have included additional species of *Sebastes*.

Each trawl zone represents an area of one kilometer in diameter centered around a specific site or sites.

Table 7.1
Species of fish collected from each PLOO trawl zone or rig fishing station (RF1–RF2) during October 2007. Pacific sanddab=PS; English sole=ES; copper rockfish=CRF; vermilion rockfish=VRF; greenblotched rockfish=GBRF; mixed rockfish=MRF.

Station	Rep 1	Rep 2	Rep 3
Zone 1	PS	PS	ES
Zone 2	PS	PS	PS
Zone 3	PS	PS	PS
Zone 4	PS	PS	PS
RF1	VRF	VRF	CRF
RF2	GBRF	GBRF	MRF

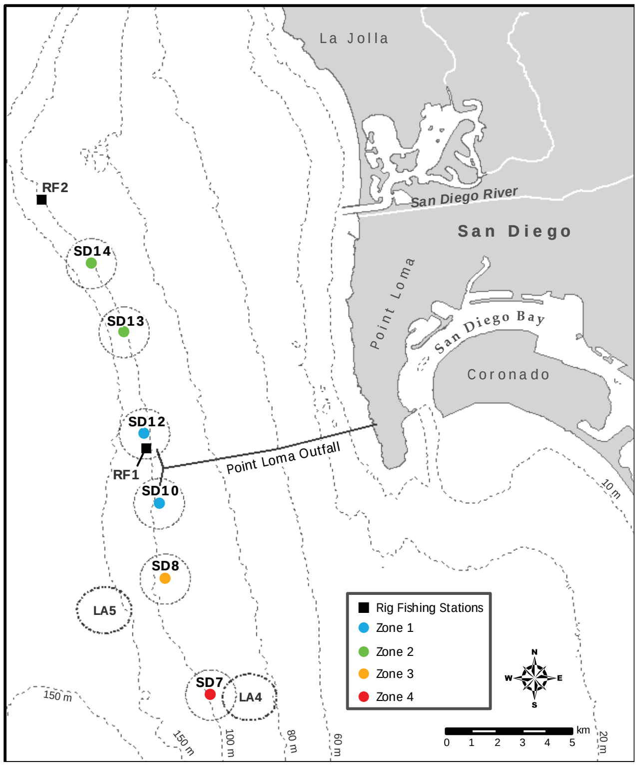

Figure 7.1
Otter trawl stations/zones and rig fishing stations for the Point Loma Ocean Outfall Monitoring Program. See text for description of zones.

Zone 1 includes the two 1-km areas surrounding nearfield stations SD10 and SD12, located just south and just north of the PLOO, respectively. Zone 2 includes the two 1-km areas surrounding northern farfield stations SD13 and SD14. Zone 3 is the 1-km area surrounding station SD8, located relatively near the LA-5 dredged materials disposal site. Zone 4 is the 1-km area surrounding station SD7, located several kilometers to the south of the outfall near the old (non-active) LA-4 disposal site. All trawl-caught fishes were collected, measured, and weighed following City of San Diego guidelines (see Chapter 6 for a description of collection methods).

Fishes targeted for collection at the rig fishing sites were caught using rod and reel fishing tackle, and then measured and weighed. The effort to collect targeted fishes was limited to five 10-minute trawls (bottom time) at each trawl station. Only fish ≥13 cm in standard length were retained for tissue analyses. These fish were sorted into no more than three composite samples per station, each containing a minimum of three individuals. Composite samples are made up of a single species except for samples that consist of mixed species of rockfish. The samples of fish were then wrapped in aluminum foil, labeled, sealed in re-sealable plastic bags, placed on dry ice, and then transported to the City's Marine Biology Laboratory where they were held in the freezer at -80°C until dissection and tissue processing.

Tissue Processing and Chemical Analyses

All dissections were performed according to the following standard techniques for tissue analysis. Each fish was partially defrosted and then cleaned with a paper towel to remove loose scales and excess mucus prior to dissection. The standard length (cm) and weight (g) of each fish were recorded (**Appendix D.1**). Dissections were carried out on Teflon® pads that were cleaned between samples. Tissue samples were then placed in glass jars, sealed, labeled, and stored in a freezer at -20 °C prior to chemical analyses. All samples were subsequently delivered to the City of San Diego Wastewater Chemistry Services Laboratory within 10 days of dissection.

The chemical constituents analyzed for each tissue sample included trace metals, chlorinated pesticides, and polychlorinated biphynel compounds (PCBs) (see **Appendix D.2**). Metals were measured as mg/kg or parts per million (ppm), while pesticides and PCBs were measured as µg/kg or parts per billion (ppb). Totals for DDT, PCB, BHC (=lindane and derivatives) and chlordane were calculated as the sum of detected constituents (i.e., total PCB = sum of all detected congeners). Values for each individual constituent are listed in **Appendix D.3**. This report includes estimated values for some parameters determined to be present in a sample with high confidence (i.e., peaks confirmed by mass-spectrometry), but at levels below the method detection limit (MDL). A detailed description of the analytical protocols may be obtained from the City of San Diego Wastewater Chemistry Services Laboratory (City of San Diego 2008).

Table 7.2

Summary of metals, pesticides, and total PCBs detected in liver tissues from fishes collected from PLOO trawl zones during 2007. The number of samples per species is indicated in parentheses; n=number of detected values; nd=not detected.

	English sole (1)		Pacific sanddab (11)					Overall
Parameter	n	Min/max	n	Min	Max	Mean	% Detected	Max
Metals (ppm)								
Aluminum	1	15.4	11	13.5	23.3	17.5	100	23.3
Antimony	1	0.77	11	0.59	1.91	1.43	100	1.91
Arsenic	1	5.7	11	0.5	2.6	1.7	100	5.7
Barium	1	0.314	11	0.225	0.548	0.437	100	0.548
Beryllium	nd	—	nd	—	—	—	—	—
Cadmium	1	0.79	11	3.10	7.43	4.51	100	7.43
Chromium	1	0.348	11	0.132	0.952	0.561	100	0.952
Copper	1	3.7	11	2.3	4.8	3.4	100	4.8
Iron	1	180	11	49	121	77	100	180
Lead	1	1.42	1	0.31	0.31	0.31	17	1.42
Manganese	1	0.82	11	0.803	1.17	0.99	100	1.17
Mercury	1	0.048	11	0.038	0.143	0.080	100	0.143
Nickel	1	0.237	11	0.190	0.753	0.457	100	0.753
Selenium	1	2.3	11	0.6	1.4	0.8	100	2.3
Silver	1	0.072	nd	—	—	—	8	0.072
Thallium	nd	—	9	1.1	2.9	1.9	75	2.9
Tin	1	1.8	11	1.9	2.9	2.6	100	2.9
Zinc	1	46.5	11	19.6	39.7	31.8	100	46.5
Pesticides (ppb)								
Total Chlordane	1	3.2	11	3.2	23.2	14.0	100	23.2
Total DDT	1	130	11	143	472	341	100	472
Total BHC	nd	—	2	3.3	4.4	3.8	17	4.4
HCB	1	5.2	11	1.1	8.3	4.7	100	8.300
Total PCB *(ppb)*	1	135	11	108	866	256	100	866
Lipids *(%wt)*	1	13	11	18	59	46	100	59

Results and Discussion

Contaminants in Trawl-Caught Fishes

Metals

Fourteen metals, including aluminum, antimony, arsenic, barium, cadmium, chromium, copper, iron, manganese, mercury, nickel, selenium, tin and zinc occurred in 100% of the liver samples analyzed from trawl-caught fishes in 2007 (**Table 7.2**). Lead, silver and thallium were also detected, but less frequently (i.e., detection rates of 8-75%), while beryllium was not detected at all. Concentrations of most metals were <10 ppm. Exceptions occurred for aluminum, iron and zinc, which all had concentrations >20 ppm in at least one sample. Of all the metals detected, iron was present in the highest concentrations in both species of fish that were analyzed. Comparisons of the frequently detected metals from Pacific sanddab samples collected closest to the discharge site (i.e., Zone 1) to those located farther away (Zones 2–4) suggest that there was no clear relationship between contaminant loads and proximity to the outfall (**Figure 7.2**).

Pesticides

Several chlorinated pesticides were detected in trawl-caught fishes during 2007 (Table 7.2).

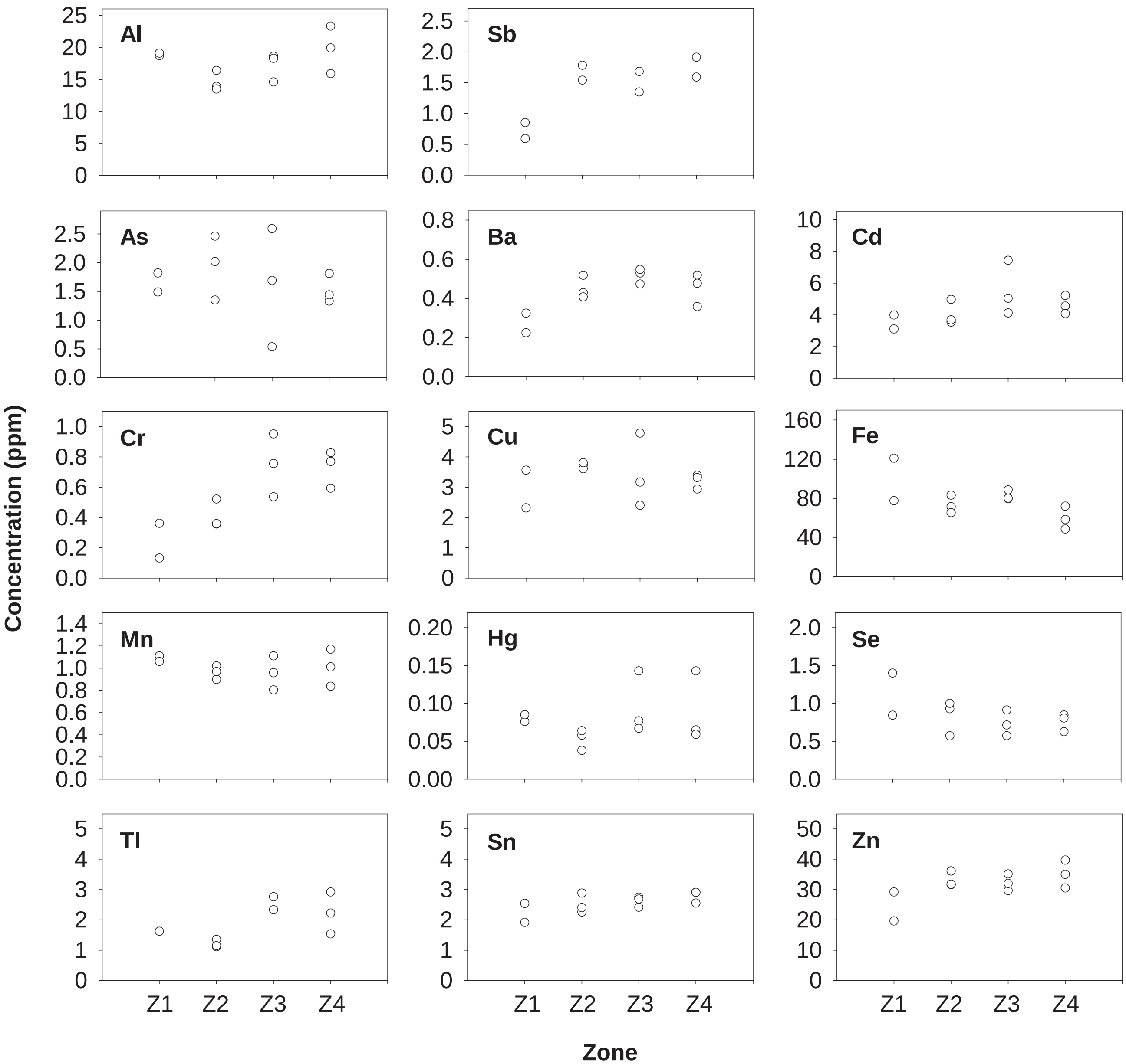

Figure 7.2

Concentrations of frequently detected metals in liver tissues of Pacific sanddabs collected from each PLOO trawl zone (Z1–Z4) during 2007. Only two Pacific sanddabs samples were collected from Zone 1; otherwise missing values = non-detects.

Individual components of total chlordane, total DDT, and total BHC are listed in Appendix D.2, while detected values of all pesticides are included in Appendix D.3. Chlordane, DDT, and HCB were detected in all samples; concentrations of total chlordane ranged from 3.2 to 23.2 ppb, total DDT ranged from 130 to 472 ppb, and HCB ranged from 1.1 to 8.3 ppb. The pesticide BHC (lindane) was also detected at concentrations up to 4.4 ppb in 17% of the samples. As with metals, there was no clear relationship between concentrations of these pesticides and proximity to the outfall (**Figure 7.3**).

PCBs

PCBs occurred in every tissue sample. All detected PCB congeners are summarized in Appendix D.3. Total PCB concentrations were highly variable overall, ranging from 108 to 866 ppb (Table 7.2). There was no clear relationship between PCB concentrations in fish livers and proximity to the outfall (Figure 7.3).

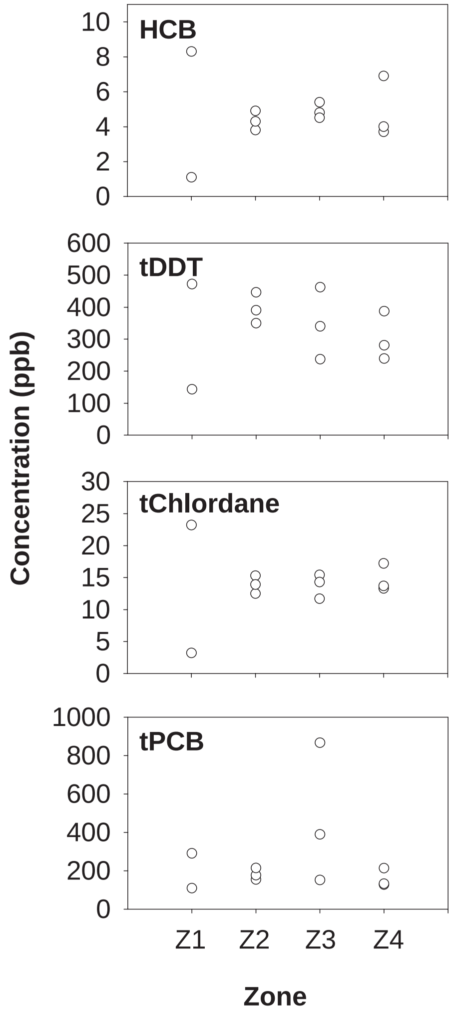

Figure 7.3
Concentrations of frequently detected chlorinated pesticides, total DDT, total Chlordane, and total PCB in liver tissues of Pacific sanddabs collected from each PLOO trawl zone (Z1–Z4) during 2007. Only two Pacific sanddabs samples were collected from Zone 1; otherwise missing values = non-detects.

Contaminants in Fishes Collected by Rig Fishing

Aluminum, arsenic, barium, cadmium, chromium, copper, iron, manganese, mercury, nickel, selenium, tin and zinc occurred in 100% of the muscle tissue samples collected from various species of rockfish at the two rig fishing stations in 2007 (**Table 7.3**). Antimony was only detected in 17% of the samples, while beryllium, lead, thallium and silver were not detected at all. The metals present in the highest concentrations were aluminum (17.8 ppm), iron (7.7 ppm), zinc (5.2 ppm) and arsenic (2.13 ppm). DDT and PCBs were detected in 100% of the muscle samples, while the pesticides HCB and BHC were detected in 67 and 17%, respectively (**Table 7.4**). Each of these contaminants was detected in relatively low concentrations ranging from 0.1 ppb for HCB to 9.2 ppb for total DDT.

To address public health concerns, contaminant concentrations found in rockfish muscle tissues were compared to national and international limits and standards (Tables 7.3 and 7.4). The United States Food and Drug Administration (FDA) has set limits on the amount of mercury, total DDT, and chlordane for seafood that is to be sold for human consumption, while there are also international standards for acceptable concentrations of various metals (see Mearns et al. 1991). Of the contaminants detected in fish muscle tissues sampled as part of the PLOO monitoring program, only arsenic and selenium occurred in concentrations equal to or slightly higher than median international standards (see Table 7.3).

In addition to addressing the above concerns, spatial patterns were analyzed for HCB, total DDT, total PCB, and for all metals that occurred frequently in muscle tissues (**Figure 7.4**). Overall, concentrations of DDT, PCB and various metals were fairly similar in the muscles of fishes captured at both rig fishing stations, which suggests that there is no relationship with proximity to the outfall. However, comparisons of contaminant loads in fishes from stations RF1 and RF2 should be considered with caution since different species of fish were collected at the two sites, and the bioaccumulation of contaminants may differ between species due to differences in their physiology and diet. This potential problem may be minimal for the fish analyzed herein as all specimens belong to the same family (Scorpaenidae), have similar life histories (i.e., bottom dwelling tertiary carnivores), and are therefore likely to have similar mechanisms of exposure to and uptake of contaminants (e.g., direct contact with sediments, similar food sources).

Table 7.3

Summary of metals detected in muscle tissues from fishes collected at PLOO rig fishing stations during October 2007. Values are expressed as parts per million (ppm). The number of samples per species is indicated in parentheses; n=number of detected values, nd=not detected. Data are compared to U.S. FDA action limits (A.L) and median international standards (I.S.) where these exist. Bold values meet or exceed these standards. See Appendix D.1 for names and periodic table symbols.

	Al	As	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Sb	Se	Sn	Zn
Copper rockfish (1)														
n	1	1	1	1	1	1	1	1	1	1	nd	1	1	1
Min/max	17.8	**1.71**	0.132	0.063	0.304	0.572	7.7	0.085	0.157	0.192	—	**0.67**	1.5	4.8
Greenblotched rockfish (2)														
n	2	2	2	2	2	2	2	2	2	2	nd	2	2	2
Min	13.6	**1.41**	0.114	0.049	0.291	0.514	5.2	0.114	0.179	0.116	—	**0.33**	1.3	4.6
Max	15.2	**1.78**	0.185	0.063	0.306	0.591	7.6	0.190	0.181	0.150	—	**0.38**	1.6	5.1
Mean	14.4	**1.59**	0.149	0.056	0.298	0.552	6.4	0.152	0.180	0.133	—	**0.36**	1.4	4.8
Mixed rockfish (1)														
n	1	1	1	1	1	1	1	1	1	1	nd	1	1	1
Min/max	12.5	1.23	0.096	0.055	0.292	0.583	6.7	0.183	0.139	0.132	—	**0.41**	1.6	4.7
Vermilion rockfish (2)														
n	2	2	2	2	2	2	2	2	2	2	1	2	2	2
Min	15.0	**1.60**	0.098	0.038	0.264	0.469	4.5	0.045	0.166	0.164	0.49	**0.37**	1.4	5.2
Max	15.5	**2.13**	0.112	0.050	0.294	0.469	5.6	0.047	1.010	0.167	0.49	**0.40**	1.6	5.2
Mean	15.3	**1.86**	0.105	0.044	0.279	0.469	5.0	0.046	0.588	0.165	0.49	**0.39**	1.5	5.2
% Detected	100	100	100	100	100	100	100	100	100	100	17	100	100	100
Max	17.8	**2.13**	0.18	0.06	0.31	0.59	7.7	0.19	1.010	0.190	0.49	**0.67**	1.6	5.2
A.L.*								1.00						
I.S.*		1.4		1	1	20		0.5				0.3	175	70

*From Mearns et al. 1991. USFDA mercury action limits and all international standards (IS) are for shellfish, but are often applied to fish.

Summary and Conclusions

Fourteen trace metals, DDT, and a combination of PCB congeners were detected in 100% of the liver tissue samples collected from two species of fish (Pacific sanddabs and English Sole) around the PLOO in 2007. All contaminant values were within the range of those reported previously for the Southern California Bight (SCB) (see Mearns et al. 1991, Allen et al. 1998). In addition, concentrations of these contaminants were generally similar to those reported previously by the City of San Diego for this survey area (e.g., City of San Diego 2007a), as well as the South Bay outfall monitoring area (e.g., City of San Diego 2007b). Concentrations of most parameters were similar across zones/stations, and no clear relationship with proximity to the outfall was evident. These results are supported by a recent special study (Parnell et al. MS, 2008).

The frequent occurrence of metals and chlorinated hydrocarbons in the tissues of fish captured off Point Loma may be due to multiple factors. Mearns et al. (1991) described the distribution of several contaminants, including arsenic, mercury, DDT and PCBs as being ubiquitous in the SCB. In fact, many metals occur naturally in the environment (see Chapter 4), although little information is available on background levels in fish tissues. In addition, Brown et al. (1986) determined that no areas of the SCB are sufficiently free of chemical contaminants to be considered reference sites. This conclusion has been supported by more recent work regarding PCBs and DDTs (e.g., Allen et al. 1998, 2002).

Table 7.4

Summary of chlorinated pesticides, total PCB, and lipids detected in muscle tissues from fishes collected at PLOO rig fishing stations during October 2007. tBHC=total BHC (lindane); HCB=hexachlorobenzene; tDDT=total DDT; tPCB=total PCB. Values are expressed in parts per billion (ppb) for all parameters except lipids, which are presented as percent weight (% wt). The number of samples per species is indicated in parentheses; n=number of detected values, nd=not detected. Data are compared to U.S. FDA action limits (A.L.) and median international standards (I.S.) for parameters where these exist.

	tBHC	HCB	tDDT	tPCB	Lipids
Copper rockfish (1)					
n	nd	nd	1	1	1
Min/max	—	—	5.4	2.3	1.8
Greenblotched rockfish (2)					
n	1	1	2	2	2
Min	0.7	0.5	4.2	1.1	0.3
Max	0.7	0.5	9.2	1.2	0.5
Mean	0.7	0.5	6.7	1.2	0.4
Mixed rockfish (1)					
n	nd	1	1	1	1
Min/max	—	0.1	6.1	2.3	0.5
Vermilion rockfish (2)					
n	nd	2	2	2	2
Min	—	0.1	3.6	2.0	0.5
Max	—	0.5	5.9	3.9	0.7
Mean	—	0.3	4.7	2.9	0.6
% Detected	17	67	100	100	100
Max	0.7	0.5	9.2	3.9	1.8
A.L.*		300	5000		
I.S.*		100	5000		

*From Table 2.3 in Mearns et al. 1991. FDA action limits for total DDT and chlordane are for fish muscle tissues and all international standards are for shellfish, but are often applied to fish.

Other factors that affect the accumulation and distribution of contaminants include the physiology and life history of different fish species. Exposure to contaminants can vary greatly between different species and among individuals of the same species depending on migration habits (Otway 1991). Fishes may also be exposed to contaminants in an area that is highly contaminated and then move into an area that is not. This may explain why many of the pesticides and PCBs detected in fish collected off Point Loma in 2007 were detected in low concentrations or not at all in sediments surrounding the outfall (see Chapter 4). In addition, intra-specific differences in feeding habits, age, reproductive status, and gender can affect the amount of contaminants a fish will retain in its tissues (e.g., Connell 1987, Evans et al. 1993).

Overall, there was no evidence that fishes collected in 2007 were contaminated by the discharge of wastewater from the PLOO. While some muscle tissue samples from sport fish collected in the region had concentrations of arsenic and selenium above the median international standard for shellfish, concentrations of mercury and DDT were below the FDA action limits for human consumption. Finally, there was no other indication of poor fish health in the region, such as the presence of fin rot, other indicators of disease, or any physical anomalies (see Chapter 6).

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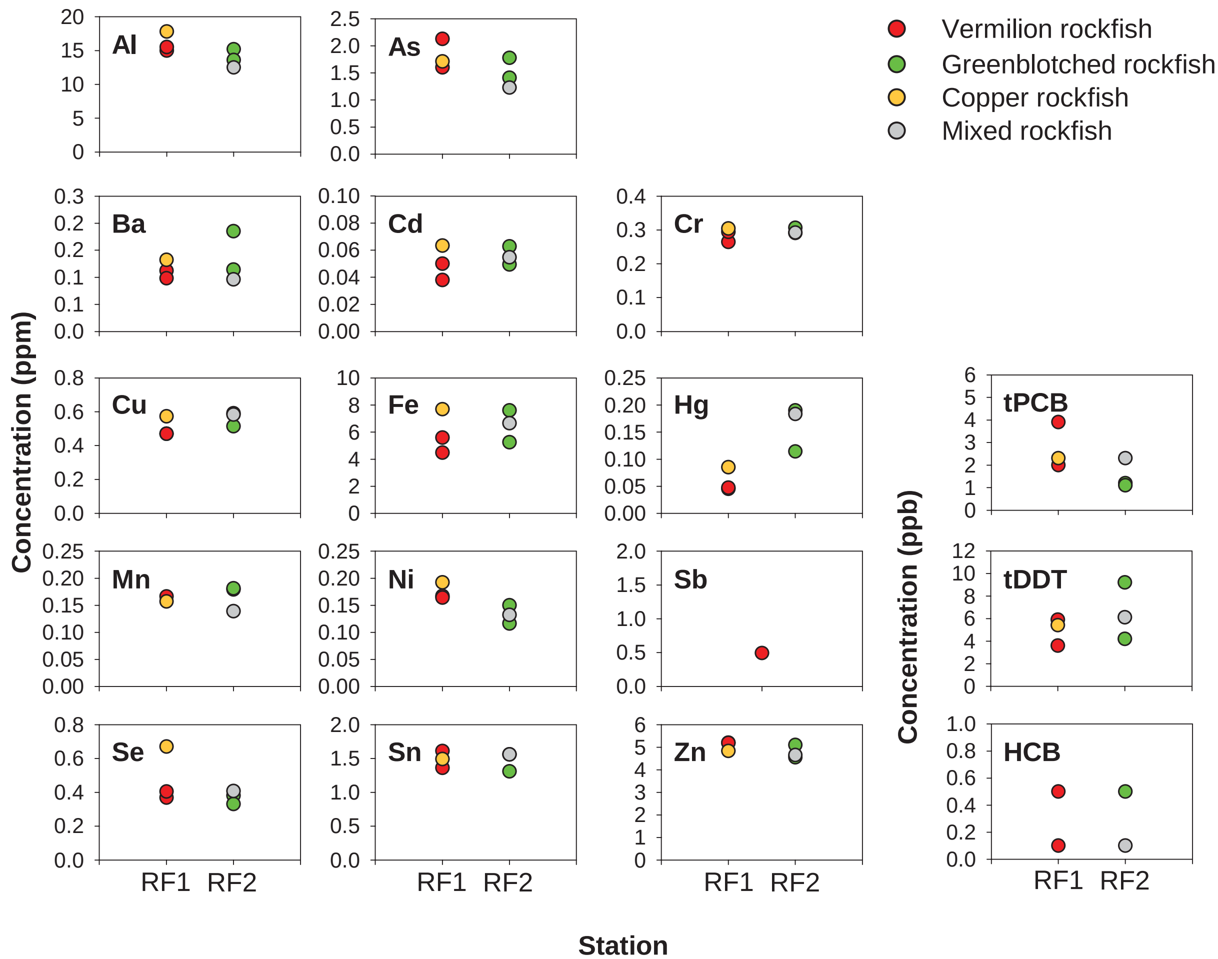

Figure 7.4

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GLOSSARY

Absorption
The movement of dissolved substances (e.g., pollution) into cells by osmosis or diffusion.

Adsorption
The adhesion of dissolved substances to the surface of sediment or on the surface of an organism (e.g., a flatfish).

Anthropogenic
Made and introduced into the environment by humans, especially pertaining to pollutants.

Assemblage
An association of interacting populations in a given habitat (e.g., an assemblage of benthic invertebrates on the ocean floor).

BACIP Analysis
An analytical tool used to assess environmental changes caused by the effects of pollution. A statistical test is applied to data from matching pairs of control and impacted sites before and after an event (i.e., initiation of wastewater discharge) to test for significant change. Significant differences are generally interpreted as being the result of the environmental change attributed to the event. Variation that is not significant reflects natural variation.

Benthic
Pertaining to the environment inhabited by organisms living on or in the ocean bottom.

Benthos
Living organisms (e.g., algae and animals) associated with the sea bottom.

Bioaccumulation
The process by which a chemical becomes accumulated in tissue over time through direct intake of contaminated water, the consumption of contaminated prey, or absorption through the skin or gills.

Biota
The living organisms within a habitat or region.

BOD
Biochemical oxygen demand (BOD) is the amount of oxygen consumed (through biological or chemical processes) during the decomposition of organic material contained in a water or sediment sample. It is a measure for certain types of organic pollution, such that high BOD levels suggest elevated levels of organic pollution.

BRI
An index that measures levels of environmental disturbance by assessing the condition of a benthic assemblage. The index was based on organisms found in the soft sediments of the Southern California Bight (SCB).

CFU
The colony-forming unit (CFU) is a measurement of density used to estimate bacteria concentrations in ocean water. The number of bacterial cells that grow to form entire colonies, which can then be quantified visually.

Control site
A geographic location that is far enough from a known pollution source (e.g., ocean outfall) to be considered representative of an undisturbed environment. Data collected from control sites are used as a reference and compared to impacted sites.

COP
The California Ocean Plan (COP) is California's ocean water quality control plan. It limits wastewater discharge and implements ocean monitoring. Federal law requires the plan to be reviewed every three years.

Crustacea
A group (subphylum) of marine invertebrates characterized by jointed legs and an exoskeleton. Crabs, shrimp, and lobster are examples.

CTD
A device consisting of a group of sensors that continually measure various physical and chemical properties such as conductivity (a proxy for salinity), temperature, and pressure (a proxy for depth) as it is lowered through the water. These parameters are used to assess the physical ocean environment.

Demersal
Organisms living on or near the bottom of the ocean and capable of active swimming.

Dendrogram
A tree-like diagram used to represent hierarchal relationships from a multivariate analysis where results from several monitoring parameters are compared among sites.

Detritus
Particles of organic material from decomposing organisms. Used as an important source of nutrients in a food web.

Diversity
A measurement of community structure which describes the abundances of different species within a community, taking into account their relative rarity or commonness.

Dominance
A measurement of community structure that describes the minimum number of species accounting for 75% of the abundance in each grab.

Echinodermata
A group (phylum) of marine invertebrates characterized by the presence of spines, a radially symmetrical body, and tube feet (e.g., sea stars, sea urchins, and sea cucumbers).

Effluent
Wastewater that flows out of a sewer, treatment plant outfall, or other point source and is discharged into a water body (e.g. ocean, river).

Halocline
A vertical zone of water in which the salinity changes rapidly with depth.

Impact site
A geographic location that has been altered by the effects of a pollution source, such as a wastewater outfall.

Indicator species
Marine invertebrates whose presence in the community reflects the health of the environment. The loss of pollution-sensitive species or the introduction of pollution-tolerant species can indicate anthropogenic impact.

Infauna
Animals living in the soft bottom sediments usually burrowing or building tubes within.

Invertebrate
An animal without a backbone. For example, a seastar, crab, or worm.

ITI
An environmental disturbance index based on the feeding structure of marine soft-bottom benthic communities and the rationale that a change in sediment quality will restructure the invertebrate community to one best suited to feed in the altered sediment type. Generally, ITI values less than 60 indicate a benthic community impacted by pollution.

Kurtosis
A measure that describes the shape (i.e., peakedness or flatness) of distribution relative to a normal distribution (bell shape) curve. Kurtosis can indicate the range of a data set, and is used herein to describe the distribution of particle sizes within sediment samples.

Macrobenthic invertebrate
Epifaunal or infaunal benthic invertebrates that are visible with the naked eye. This group typically includes those animals larger than meiofauna and smaller than megafauna. These animals are collected in grab samples from soft-bottom marine habitats and retained on a 1-mm mesh screen.

MDL
The EPA defines MDL (method detection limit) as "the minimum concentration that can be determined with 99% confidence that the true concentration is greater than zero."

Megabenthic invertebrate
A larger, usually epibenthic and motile, bottom-dwelling animal such as a sea urchin, crab, or snail. These animals are typically collected by otter trawl nets with a minimum mesh size of 1 cm.

Mollusca
A taxonomic group (phylum) of invertebrates characterized as having a muscular foot, visceral mass, and a shell. Examples include snails, clams, and octupuses.

Motile
Self-propelled or actively moving.

Niskin bottle
A long plastic tube allowing seawater to pass through until the caps at both ends are triggered to close from the surface. They often are arrayed with several others in a rosette sampler to collect water at various depths.

Non-point source
Pollution sources from numerous points, not a specific outlet, generally carried into the ocean by storm water runoff.

NPDES
The National Pollutant Discharge Elimination System (NPDES) is a federal permit program that controls water pollution by regulating point sources that discharge pollutants into waters of the United States.

Ophiuroidea
A taxonomic group (class) of echinoderms that comprises the brittle stars. Brittle stars usually have five long, flexible arms and a central disk-shaped body.

PAHs
The USGS defines polycyclic aromatic hydrocarbons (PAHs) as, "hydrocarbon compounds with multiple benzene rings. PAHs are typical components of asphalts, fuels, oils, and greases."

PCBs
The EPA defines polychlorinated biphenyls (PCBs) as, "a category, or family, of chemical compounds formed by the addition of chlorine (C_{l2}) to biphenyl ($C_{12}H_{10}$), which is a dual-ring structure comprising two 6-carbon benzene rings linked by a single carbon-carbon bond."

PCB Congeners
The EPA defines a PCB congener as, "one of the 209 different PCB compounds. A congener may have between one and 10 chlorine atoms, which may be located at various positions on the PCB molecule."

Phi
The conventional unit of sediment size based on the log of sediment grain diameter. The larger the Phi number, the smaller the grain size.

Plankton
Animal and plant-like organisms, usually microscopic, that are passively carried by the ocean currents.

PLOO
The Point Loma Ocean Outfall (PLOO) is the underwater pipe originating at the Point Loma Wastewater Treatment Plant and used to discharge treated wastewater. It extends 7.2 km (4.5 miles) offshore and discharges into 96 m (320 ft) of water.

Point source
Pollution discharged from a single source (e.g., municipal wastewater treatment plant, storm drain) to a specific location through a pipe or outfall.

Polychaeta
A taxonomic group (class) of invertebrates characterized as having worm-like features, segments, and bristles or tiny hairs. Examples include bristle worms and tube worms.

Pycnocline
A depth zone in the ocean where sea water density changes rapidly with depth and typically is associated with a decline in temperature and increase in salinity.

Recruitment
The retention of young individuals into the adult population in an open ocean environment.

Relict sand
Coarse reddish-brown sand that is a remnant of a pre-existing formation after other parts have disappeared. Typically originating from land and transported to the ocean bottom through erosional processes.

Rosette sampler
A device consisting of a round metal frame housing a CTD in the center and multiple bottles (see Niskin bottle) arrayed about the perimeter. As the instrument is lowered through the water column, continuous measurements of various physical and chemical parameters are recorded by the CTD. Discrete water samples are captured at desired depths by the bottles.

SBOO
The South Bay Ocean Outfall (SBOO) is the underwater pipe originating at the International Wastewater Treatment Plant and used to discharge treated wastewater. It extends 5.6 km (3.5 miles) offshore and discharges into about 27 m (90 ft) of water.

SBWRP
The South Bay Water Reclamation Plant (SBWRP) provides local wastewater treatment services and reclaimed water to the South Bay. The plant began operation in 2002 and has a wastewater treatment capacity of 15 million gallons a day.

SCB
The Southern California Bight (SCB) is the geographic region that stretches from Point Conception, U.S.A. to Cabo Colnett, Mexico and encompasses nearly 80,000 km^2 of coastal land and sea.

Shell hash
Sediment composed of shell fragments.

Skewness
A measure of the lack of symmetry in a distribution or data set. Skewness can indicate where most of the data lies within a distribution. It can be used to describe the distribution of particle sizes within sediment grain size samples.

Sorting
The range of grain sizes that comprises marine sediments. Also refers to the process by which sediments of similar size are naturally segregated during transport and deposition according to the velocity and transporting medium. Well sorted sediments are of similar size (such as desert sand), while poorly sorted sediments have a wide range of grain sizes (as in a glacial till).

Species richness
The number of species per sample or unit area. A metric used to evaluate the health of macrobenthic communities.

Standard length
The measurement of a fish from the most forward tip of the body to the base of the tail (excluding the tail fin rays). Fin rays can sometimes be eroded by pollution or preservation so measurement that includes them (i.e., total length) is considered less reliable.

Tertiary carnivore
A tertiary carnivore is a carnivore (flesh-eater) that eats other carnivores. In a linear food chain, primary consumers (herbivores) eat plants and algae (producers). The next trophic level consists of secondary consumers, i.e. carnivores that eat herbivores. These secondary carnivores may be in turn may be preyed upon by other (tertiary) carnivores.

Thermocline
The zone in a thermally stratified body of water that separates warmer surface water from colder deep water. At a thermocline, temperature changes rapidly over a short depth.

Tissue burden
The total amount of measured chemicals that are present in the tissue (e.g. fish muscle).

Transmissivity
A measure of water clarity based upon the ability of water to transmit light along a straight path. Light that is scattered or absorbed by particulates (e.g., plankton, suspended solid materials) decreases the transmissivity (or clarity) of the water.

Upwelling
The movement of nutrient-rich and typically cold water from the depths of the ocean to the surface waters.

USGS
The United States Geological Survey (USGS) provides geologic, topographic, and hydrologic information on water, biological, energy, and mineral resources.

Van Dorn bottle
A water sampling device made of a plastic tube open at both ends that allows water to flow through. Rubber caps at the tube ends can be triggered to close underwater to collect water at a specified depth.

Van Veen grab
A mechanical device designed to collect bottom sediment samples. The device consists of a pair of hinged jaws and a release mechanism that allows the opened jaws to close and entrap a 0.1 m^2 sediment sample once they touch bottom.

Wastewater
A mixture of water and waste materials originating from homes, businesses, industries, and sewage treatment plants.

ZID
The zone of initial dilution (ZID) is the region of initial mixing of the surrounding receiving waters with wastewater from the diffuser ports of an outfall. This area includes the underlying seabed. In the ZID, the environment is chronically exposed to pollutants and often is the most impacted.

Appendix A

Supporting Data

2007 PLOO Stations

Microbiology

Appendix A.1

Summary of samples with elevated total coliform concentrations (> 1000 CFU/100 mL) collected at PLOO offshore water quality stations sampled in 2007. Values are expressed as CFU/100 mL; Total = total coliform; Fecal = fecal coliform; Entero = entercoccus; F:T = fecal to total coliform ratio.

Date	Station	Sample depth (m)	Total	Fecal	Entero	F:T
January 9	F19	80	>16,000	2400	340	0.15
January 9	F20	60	>16,000	1200	40	0.08
January 9	F20	80	>16,000	980	40	0.06
January 9	F21	60	2800	380	50	0.14
January 9	F21	80	2400	960	200	0.40
January 9	F22	80	2000	280	88	0.14
January 9	F30	60	1800	240	60	0.13
January 9	F30	80	>16,000	6400	740	0.40
January 9	F31	80	12,000	3800	500	0.32
January 9	F32	80	>16,000	3000	400	0.19
January 9	F33	80	1200	260	58	0.22
January 10	F18	80	1800	300	140	0.17
January 10	F26	80	1000	100	64	0.10
January 10	F27	80	1300	460	110	0.35
January 10	F27	98	1500	440	120	0.29
January 10	F28	60	1200	110	42	0.09
January 10	F28	80	5600	600	120	0.11
January 10	F29	80	7200	1200	280	0.17
January 19	F23	80	7400	1300	240	0.18
January 19	F25	80	1000	64	44	0.06
January 19	F34	80	7000	1200	220	0.17
January 19	F35	80	1000	64	50	0.06
January 19	F35	98	1600	220	50	0.14
April 9	F23	60	1000	240	14	0.24
April 9	F23	80	12,000	2600	320	0.22
April 9	F24	80	9000	4000	240	0.44
April 9	F25	80	5600	1100	160	0.20
April 9	F34	98	2600	680	56	0.26
April 11	F10	60	2400	340	2	0.14
April 11	F19	60	1400	180	66	0.13
April 11	F20	60	9000	2200	300	0.24
April 11	F20	80	3000	300	66	0.10
April 11	F21	80	5000	1600	220	0.32
April 11	F22	80	6400	760	94	0.12
April 11	F30	60	>16,000	7200	660	0.45
April 11	F30	80	>16,000	3400	580	0.21
April 11	F30	98	1300	160	56	0.12
April 11	F31	98	3200	420	72	0.13
April 11	F32	80	1200	300	32	0.25
April 11	F32	98	2000	380	34	0.19
April 11	F33	98	1300	240	36	0.18
April 17	F16	25	4400	760	150	0.17
April 17	F17	1	2800	520	110	0.19
April 17	F17	25	4600	1100	300	0.24
April 17	F18	80	13,000	2400	260	0.18
April 17	F27	60	1100	200	20	0.18
April 17	F28	60	14,000	1100	500	0.08

Appendix A.1 *continued*

Date	Station	Sample depth (m)	Total	Fecal	Entero	F:T
April 17	F28	80	1000	86	28	0.09
April 17	F29	60	>16,000	2000	280	0.13
April 17	F29	80	1200	92	28	0.08
July 2	F23	60	15,000	4200	300	0.28
July 2	F24	80	1600	160	52	0.10
July 2	F25	60	2600	520	120	0.20
July 2	F25	80	2400	340	48	0.14
July 2	F34	60	18,000	1800	640	0.10
July 2	F35	60	2400	340	38	0.14
July 2	F36	60	7200	960	130	0.13
July 3	F20	80	2400	300	42	0.13
July 3	F22	80	3400	500	68	0.15
July 3	F32	60	>16,000	6000	720	0.38
July 3	F33	60	12,000	2000	500	0.17
July 5	F29	80	6200	1600	44	0.26
October 9	F08	1	1400	140	6	0.10
October 9	F09	60	1400	200	54	0.14
October 9	F19	80	1000	240	38	0.24
October 9	F30	98	4800	860	48	0.18
October 10	F15	80	5400	1200	280	0.22
October 10	F17	80	1200	100	66	0.08
October 10	F27	80	1300	240	14	0.18
October 10	F28	80	8400	800	200	0.10
October 10	F28	98	6200	1400	180	0.23
October 10	F29	80	5600	720	30	0.13
October 10	F29	98	>16,000	4800	200	0.30

Appendix A.2

Summary of compliance with California Ocean Plan water contact standards for PLOO shore stations during 2007. The values reflect the number of days that each station exceeded the 30-day total coliform, 10,000 total coliform, 60-day fecal coliform, and fecal geometric mean standards (see Chapter 3, Box 3.1). Shore stations are listed left to right from south to north.

30-Day total coliform standard

Month	# days	D4	D5	D7	D8	D9	D10	D11	D12
January	31	0	0	0	0	0	0	0	0
February	28	0	0	0	0	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0
Percent compliance		**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

10,000 Total coliform standard

Month	# days	D4	D5	D7	D8	D9	D10	D11	D12
January	31	0	0	0	0	0	0	0	0
February	28	0	0	0	0	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0
Percent compliance		**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Appendix A.2 *continued*

60-Day fecal coliform standard

Month	# days	D4	D5	D7	D8	D9	D10	D11	D12
January	31	0	0	0	22	0	0	0	0
February	28	0	0	0	0	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	18	0	0	0	0
November	30	0	0	0	30	0	0	0	0
December	31	0	0	0	12	0	0	29	0
Percent compliance		**100%**	**100%**	**100%**	**78%**	**100%**	**100%**	**92%**	**100%**

Fecal geometric mean standard

Month	# days	D4	D5	D7	D8	D9	D10	D11	D12
January	31	0	0	0	0	0	0	0	0
February	28	0	0	0	0	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	12	0	0	0	0
November	30	0	0	0	18	0	0	0	0
December	31	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Percent compliance		**100%**	**100%**	**100%**	**92%**	**100%**	**100%**	**100%**	**100%**

Appendix A.3

Summary of compliance with California Ocean Plan water contact standards for PLOO kelp bed stations during 2007. The values reflect the number of days that each station exceeded the 30-day total, 10,000 total coliform, 60-day fecal coliform, and geometric mean standards (see Chapter 3, Box 3.1). Kelp stations are listed left to right from south to north by depth contour.

30-Day total coliform standard

		9 m stations			18 m stations				
Month	**# days**	**C4**	**C5**	**C6**	**A1**	**A7**	**A6**	**C7**	**C8**
January	31	0	0	0	0	0	0	0	0
February	28	0	0	0	0	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0
Percent compliance		**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

10,000 Total coliform standard

		9 m stations			18 m stations				
Month	**# days**	**C4**	**C5**	**C6**	**A1**	**A7**	**A6**	**C7**	**C8**
January	31	0	0	0	0	0	0	0	0
February	28	0	0	0	0	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0
Percent compliance		**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

60-Day fecal coliform standard

		9 m stations			18 m stations				
Month	**# days**	**C4**	**C5**	**C6**	**A1**	**A7**	**A6**	**C7**	**C8**
January	31	0	0	0	0	0	0	0	0
February	28	0	0	0	0	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0
Percent compliance		**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Fecal geometric mean standard

		9 m stations			18 m stations				
Month	**# days**	**C4**	**C5**	**C6**	**A1**	**A7**	**A6**	**C7**	**C8**
January	31	0	0	0	0	0	0	0	0
February	28	0	0	0	0	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0
Percent compliance		**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Appendix B

Supporting Data

2007 PLOO Stations

Sediment Characteristics

Appendix B.1

Constituents and method detection limits (MDL) for sediment samples analyzed for the PLOO monitoring program during 2007.

Parameter	MDL	Parameter	MDL
Sulfides-Total (ppm)	0.14	Total Solids (%wt)	0.24
Total Nitrogen (%wt)	0.01	Total Volatile Solids (%wt)	0.11
Total Organic Carbon (%wt)	0.01	Biological Oxygen Demand (ppm)	2.00
Metals (ppm)			
Aluminum (Al)	1.20	Lead (Pb)	0.14
Antimony (Sb)	0.13	Manganese (Mn)	0.00
Arsenic (As)	0.33	Mercury (Hg)	0.00
Barium (Ba)	0.00	Nickel (Ni)	0.04
Beryllium (Be)	0.00	Selenium (Se)	0.24
Cadmium (Cd)	0.01	Silver (Ag)	0.01
Chromium (Cr)	0.02	Thallium (Tl)	0.22
Copper (Cu)	0.03	Tin (Sn)	0.06
Iron (Fe)	0.76	Zinc (Zn)	0.05
Pesticides (ppt)			
Aldrin	700	Cis Nonachlor	700
Alpha Endosulfan	700	Gamma (trans) Chlordane	700
Beta Endosulfan	700	Heptachlor	700
Dieldrin	700	Heptachlor epoxide	700
Endosulfan Sulfate	700	Methoxychlor	700
Endrin	700	Oxychlordane	700
Endrin aldehyde	700	Trans Nonachlor	700
Hexachlorobenzene	400	o,p-DDD	400
Mirex	700	o,p-DDE	700
BHC, Alpha isomer	400	o,p-DDT	700
BHC, Beta isomer	400	p,-p-DDMU	*
BHC, Delta isomer	400	p,p-DDD	700
BHC, Gamma isomer	400	p,p-DDE	400
Alpha (cis) Chlordane	700	p,p-DDT	700

* No MDL available for this parameter

Appendix B.1 *continued*

Parameter	MDL	Parameter	MDL
Polychlorinated Biphenyl Congeners (PCBs) (ppt)			
PCB 18	700	PCB 126	1500
PCB 28	700	PCB 128	700
PCB 37	700	PCB 138	700
PCB 44	700	PCB 149	700
PCB 49	700	PCB 151	700
PCB 52	700	PCB 153/168	700
PCB 66	700	PCB 156	700
PCB 70	700	PCB 157	700
PCB 74	700	PCB 158	700
PCB 77	700	PCB 167	700
PCB 81	700	PCB 169	700
PCB 87	700	PCB 170	700
PCB 99	700	PCB 177	700
PCB 101	700	PCB 180	400
PCB 105	700	PCB 183	700
PCB 110	700	PCB 187	700
PCB 114	700	PCB 189	400
PCB 118	700	PCB 194	700
PCB 119	700	PCB 201	700
PCB 123	700	PCB 206	700
Polycyclic Aromatic Hydrocarbons (PAHs) (ppb)			
1-methylnaphthalene	70	Benzo[K]fluoranthene	82
1-methylphenanthrene	41	Benzo[e]pyrene	57
2,3,5-trimethylnaphthalene	134	Biphenyl	89
2,6-dimethylnaphthalene	106	Chrysene	36
2-methylnaphthalene	102	Dibenzo(A,H)anthracene	32
3,4-benzo(B)fluoranthene	63	Fluoranthene	24
Acenaphthene	11	Fluorene	18
Acenaphthylene	11	Indeno(1,2,3-CD)pyrene	76
Anthracene	14	Naphthalene	21
Benzo[A]anthracene	34	Perylene	58
Benzo[A]pyrene	55	Phenanthrene	32

Appendix B.2

Summary of detected pesticides and the constituents that make up total DDT, total PCB, total chlordane, total BHC, and total PAH in each sediment sample collected as part of the PLOO monitoring program during 2007.

Date	Station	Parameter	Value	Units
2007-1	B-10	1-methylnaphthalene	11.5	µg/kg
2007-1	B-10	1-methylphenanthrene	6.9	µg/kg
2007-1	B-10	2,6-dimethylnaphthalene	11.400	µg/kg
2007-1	B-10	2-methylnaphthalene	31	µg/kg
2007-1	B-10	Anthracene	3.7	µg/kg
2007-1	B-10	Benzo[A]anthracene	31.300	µg/kg
2007-1	B-10	Biphenyl	14.6	µg/kg
2007-1	B-10	Chrysene	7.2	µg/kg
2007-1	B-10	Fluorene	4.3	µg/kg
2007-1	B-10	Naphthalene	42.600	µg/kg
2007-1	B-10	p,p-DDE	140	ng/kg
2007-1	B-10	Phenanthrene	19.100	µg/kg
2007-1	B-11	1-methylnaphthalene	12.7	µg/kg
2007-1	B-11	1-methylphenanthrene	8	µg/kg
2007-1	B-11	2,6-dimethylnaphthalene	3.9	µg/kg
2007-1	B-11	2-methylnaphthalene	31.900	µg/kg
2007-1	B-11	Anthracene	4.4	µg/kg
2007-1	B-11	Benzo[A]anthracene	37.5	µg/kg
2007-1	B-11	Biphenyl	14.6	µg/kg
2007-1	B-11	Chrysene	12.900	µg/kg
2007-1	B-11	Naphthalene	40.800	µg/kg
2007-1	B-11	p,p-DDE	290	ng/kg
2007-1	B-11	Phenanthrene	18.7	µg/kg
2007-1	B-12	1-methylnaphthalene	8.300	µg/kg
2007-1	B-12	2-methylnaphthalene	23.600	µg/kg
2007-1	B-12	Benzo[A]anthracene	29.5	µg/kg
2007-1	B-12	Biphenyl	13.800	µg/kg
2007-1	B-12	Chrysene	6.7	µg/kg
2007-1	B-12	Fluorene	3.1	µg/kg
2007-1	B-12	Hexachlorobenzene	160	ng/kg
2007-1	B-12	Naphthalene	29.300	µg/kg
2007-1	B-12	p,p-DDE	120	ng/kg
2007-1	B-12	Phenanthrene	11.900	µg/kg
2007-1	B-8	1-methylnaphthalene	11	µg/kg
2007-1	B-8	2,6-dimethylnaphthalene	8.650	µg/kg
2007-1	B-8	2-methylnaphthalene	31.5	µg/kg
2007-1	B-8	Anthracene	2.45	µg/kg
2007-1	B-8	Benzo[A]anthracene	26.800	µg/kg
2007-1	B-8	Biphenyl	12.5	µg/kg
2007-1	B-8	Chrysene	7.8	µg/kg

Appendix B.2 *continued*

Date	Station	Parameter	Value	Units
2007-1	B-8	Fluoranthene	4.45	µg/kg
2007-1	B-8	Hexachlorobenzene	300	ng/kg
2007-1	B-8	Naphthalene	28.600	µg/kg
2007-1	B-8	p,p-DDE	315	ng/kg
2007-1	B-8	PCB 180	29	ng/kg
2007-1	B-8	Phenanthrene	15.7	µg/kg
2007-1	B-8	Pyrene	14.400	µg/kg
2007-1	B-9	1-methylnaphthalene	11.5	µg/kg
2007-1	B-9	2,6-dimethylnaphthalene	7.7	µg/kg
2007-1	B-9	2-methylnaphthalene	28.5	µg/kg
2007-1	B-9	Acenaphthylene	1.35	µg/kg
2007-1	B-9	Anthracene	4.25	µg/kg
2007-1	B-9	Benzo[A]anthracene	32.5	µg/kg
2007-1	B-9	Benzo[G,H,I]perylene	12.900	µg/kg
2007-1	B-9	Biphenyl	13.7	µg/kg
2007-1	B-9	Chrysene	6.35	µg/kg
2007-1	B-9	Fluorene	5.7	µg/kg
2007-1	B-9	Naphthalene	36.900	µg/kg
2007-1	B-9	p,p-DDE	150	ng/kg
2007-1	B-9	Phenanthrene	16.400	µg/kg
2007-1	E-1	1-methylnaphthalene	4.75	µg/kg
2007-1	E-1	1-methylphenanthrene	4.35	µg/kg
2007-1	E-1	2,6-dimethylnaphthalene	6.9	µg/kg
2007-1	E-1	2-methylnaphthalene	22.600	µg/kg
2007-1	E-1	3,4-benzo(B)fluoranthene	11.7	µg/kg
2007-1	E-1	Anthracene	2.3	µg/kg
2007-1	E-1	Benzo[A]anthracene	17.900	µg/kg
2007-1	E-1	Biphenyl	5.2	µg/kg
2007-1	E-1	Chrysene	9.2	µg/kg
2007-1	E-1	Fluoranthene	10.2	µg/kg
2007-1	E-1	Hexachlorobenzene	100	ng/kg
2007-1	E-1	Naphthalene	21.800	µg/kg
2007-1	E-1	p,p-DDE	510	ng/kg
2007-1	E-1	PCB 101	1000	ng/kg
2007-1	E-1	PCB 105	280	ng/kg
2007-1	E-1	PCB 110	910	ng/kg
2007-1	E-1	PCB 118	750	ng/kg
2007-1	E-1	PCB 128	91	ng/kg
2007-1	E-1	PCB 138	900	ng/kg
2007-1	E-1	PCB 149	550	ng/kg
2007-1	E-1	PCB 151	210	ng/kg
2007-1	E-1	PCB 153/168	270	ng/kg

Appendix B.2 *continued*

Date	Station	Parameter	Value	Units
2007-1	E-1	PCB 156	88	ng/kg
2007-1	E-1	PCB 158	120	ng/kg
2007-1	E-1	PCB 167	140	ng/kg
2007-1	E-1	PCB 170	110	ng/kg
2007-1	E-1	PCB 177	130	ng/kg
2007-1	E-1	PCB 180	200	ng/kg
2007-1	E-1	PCB 187	230	ng/kg
2007-1	E-1	PCB 194	46	ng/kg
2007-1	E-1	PCB 44	210	ng/kg
2007-1	E-1	PCB 52	640	ng/kg
2007-1	E-1	PCB 70	320	ng/kg
2007-1	E-1	PCB 87	420	ng/kg
2007-1	E-1	PCB 99	360	ng/kg
2007-1	E-1	Phenanthrene	8.45	µg/kg
2007-1	E-1	Pyrene	22.2	µg/kg
2007-1	E-11	1-methylnaphthalene	9	µg/kg
2007-1	E-11	2,6-dimethylnaphthalene	5.7	µg/kg
2007-1	E-11	2-methylnaphthalene	24.300	µg/kg
2007-1	E-11	Anthracene	2.7	µg/kg
2007-1	E-11	Benzo[A]anthracene	30.400	µg/kg
2007-1	E-11	Biphenyl	13	µg/kg
2007-1	E-11	Chrysene	9.6	µg/kg
2007-1	E-11	Naphthalene	28.5	µg/kg
2007-1	E-11	p,p-DDE	160	ng/kg
2007-1	E-11	PCB 110	81	ng/kg
2007-1	E-11	Phenanthrene	11.300	µg/kg
2007-1	E-14	1-methylnaphthalene	9.900	µg/kg
2007-1	E-14	2,6-dimethylnaphthalene	7.4	µg/kg
2007-1	E-14	2-methylnaphthalene	23.7	µg/kg
2007-1	E-14	Acenaphthylene	4	µg/kg
2007-1	E-14	Anthracene	3.4	µg/kg
2007-1	E-14	Benzo[A]anthracene	31.600	µg/kg
2007-1	E-14	Biphenyl	13.6	µg/kg
2007-1	E-14	Chrysene	12.7	µg/kg
2007-1	E-14	Fluorene	3.7	µg/kg
2007-1	E-14	Naphthalene	47.300	µg/kg
2007-1	E-14	p,p-DDE	130	ng/kg
2007-1	E-14	Phenanthrene	13.5	µg/kg
2007-1	E-15	1-methylnaphthalene	8.6	µg/kg
2007-1	E-15	2-methylnaphthalene	23.100	µg/kg
2007-1	E-15	Anthracene	2.9	µg/kg
2007-1	E-15	Benzo[A]anthracene	28.900	µg/kg

Appendix B.2 *continued*

Date	Station	Parameter	Value	Units
2007-1	E-15	Biphenyl	12.2	µg/kg
2007-1	E-15	Chrysene	13.900	µg/kg
2007-1	E-15	Naphthalene	31.400	µg/kg
2007-1	E-15	p,p-DDE	140	ng/kg
2007-1	E-15	Phenanthrene	12	µg/kg
2007-1	E-17	1-methylnaphthalene	6.9	µg/kg
2007-1	E-17	2,6-dimethylnaphthalene	4.5	µg/kg
2007-1	E-17	2-methylnaphthalene	21.400	µg/kg
2007-1	E-17	Anthracene	2.3	µg/kg
2007-1	E-17	Benzo[A]anthracene	30	µg/kg
2007-1	E-17	Biphenyl	11	µg/kg
2007-1	E-17	Chrysene	6.3	µg/kg
2007-1	E-17	Fluorene	4	µg/kg
2007-1	E-17	Naphthalene	28.5	µg/kg
2007-1	E-17	p,p-DDE	150	ng/kg
2007-1	E-17	PCB 110	68	ng/kg
2007-1	E-17	Phenanthrene	13.2	µg/kg
2007-1	E-19	1-methylnaphthalene	10.800	µg/kg
2007-1	E-19	2,6-dimethylnaphthalene	6.3	µg/kg
2007-1	E-19	2-methylnaphthalene	28.2	µg/kg
2007-1	E-19	Anthracene	4.6	µg/kg
2007-1	E-19	Benzo[A]anthracene	36.700	µg/kg
2007-1	E-19	Biphenyl	12.7	µg/kg
2007-1	E-19	Chrysene	14.400	µg/kg
2007-1	E-19	Naphthalene	32.400	µg/kg
2007-1	E-19	p,p-DDE	295	ng/kg
2007-1	E-19	PCB 180	20	ng/kg
2007-1	E-19	Phenanthrene	13.800	µg/kg
2007-1	E-2	1-methylnaphthalene	10.2	µg/kg
2007-1	E-2	2,6-dimethylnaphthalene	9.800	µg/kg
2007-1	E-2	2-methylnaphthalene	30.800	µg/kg
2007-1	E-2	Benzo[A]anthracene	18.5	µg/kg
2007-1	E-2	Biphenyl	11.6	µg/kg
2007-1	E-2	Hexachlorobenzene	470	ng/kg
2007-1	E-2	Naphthalene	34.100	µg/kg
2007-1	E-2	p,p-DDE	280	ng/kg
2007-1	E-2	PCB 101	150	ng/kg
2007-1	E-2	PCB 110	110	ng/kg
2007-1	E-2	PCB 118	77	ng/kg
2007-1	E-2	PCB 138	180	ng/kg
2007-1	E-2	PCB 153/168	62	ng/kg
2007-1	E-2	PCB 170	25	ng/kg

Appendix B.2 *continued*

Date	Station	Parameter	Value	Units
2007-1	E-2	PCB 180	230	ng/kg
2007-1	E-2	Phenanthrene	8.650	µg/kg
2007-1	E-2	Pyrene	18.400	µg/kg
2007-1	E-20	1-methylnaphthalene	9.550	µg/kg
2007-1	E-20	2,6-dimethylnaphthalene	9	µg/kg
2007-1	E-20	2-methylnaphthalene	31.900	µg/kg
2007-1	E-20	Anthracene	2.9	µg/kg
2007-1	E-20	Benzo[A]anthracene	28.7	µg/kg
2007-1	E-20	Biphenyl	14.6	µg/kg
2007-1	E-20	Chrysene	1.7	µg/kg
2007-1	E-20	Fluorene	2.35	µg/kg
2007-1	E-20	Naphthalene	24.100	µg/kg
2007-1	E-20	p,p-DDE	280	ng/kg
2007-1	E-20	Phenanthrene	16.300	µg/kg
2007-1	E-21	1-methylnaphthalene	9.900	µg/kg
2007-1	E-21	2-methylnaphthalene	32.900	µg/kg
2007-1	E-21	Benzo[A]anthracene	29.5	µg/kg
2007-1	E-21	Biphenyl	11.7	µg/kg
2007-1	E-21	Fluorene	4.3	µg/kg
2007-1	E-21	Naphthalene	26.5	µg/kg
2007-1	E-21	p,p-DDE	160	ng/kg
2007-1	E-21	Phenanthrene	12.6	µg/kg
2007-1	E-23	1-methylnaphthalene	22.600	µg/kg
2007-1	E-23	2,6-dimethylnaphthalene	17.300	µg/kg
2007-1	E-23	2-methylnaphthalene	43.700	µg/kg
2007-1	E-23	Acenaphthene	6.8	µg/kg
2007-1	E-23	Anthracene	10.5	µg/kg
2007-1	E-23	Benzo[A]anthracene	35.600	µg/kg
2007-1	E-23	Biphenyl	18.5	µg/kg
2007-1	E-23	Chrysene	11	µg/kg
2007-1	E-23	Fluorene	7.5	µg/kg
2007-1	E-23	Naphthalene	61	µg/kg
2007-1	E-23	p,p-DDE	260	ng/kg
2007-1	E-23	PCB 110	130	ng/kg
2007-1	E-23	PCB 118	52	ng/kg
2007-1	E-23	PCB 180	120	ng/kg
2007-1	E-23	Phenanthrene	25.300	µg/kg
2007-1	E-25	1-methylnaphthalene	9	µg/kg
2007-1	E-25	2-methylnaphthalene	28	µg/kg
2007-1	E-25	Benzo[A]anthracene	26.300	µg/kg
2007-1	E-25	Biphenyl	13.300	µg/kg
2007-1	E-25	Chrysene	8.5	µg/kg

Appendix B.2 *continued*

Date	Station	Parameter	Value	Units
2007-1	E-25	Fluorene	2.6	µg/kg
2007-1	E-25	Naphthalene	29.300	µg/kg
2007-1	E-25	p,p-DDE	215	ng/kg
2007-1	E-25	Phenanthrene	15.7	µg/kg
2007-1	E-26	1-methylnaphthalene	9.7	µg/kg
2007-1	E-26	2-methylnaphthalene	23.800	µg/kg
2007-1	E-26	Acenaphthene	4	µg/kg
2007-1	E-26	Anthracene	4.3	µg/kg
2007-1	E-26	Benzo[A]anthracene	32.300	µg/kg
2007-1	E-26	Biphenyl	11.800	µg/kg
2007-1	E-26	Chrysene	13.1	µg/kg
2007-1	E-26	Hexachlorobenzene	380	ng/kg
2007-1	E-26	Naphthalene	36.800	µg/kg
2007-1	E-26	p,p-DDE	330	ng/kg
2007-1	E-26	Phenanthrene	17.400	µg/kg
2007-1	E-3	1-methylnaphthalene	6.65	µg/kg
2007-1	E-3	2,6-dimethylnaphthalene	6	µg/kg
2007-1	E-3	2-methylnaphthalene	22.600	µg/kg
2007-1	E-3	Anthracene	2.9	µg/kg
2007-1	E-3	Benzo[A]anthracene	20.600	µg/kg
2007-1	E-3	BHC, Beta isomer	670	ng/kg
2007-1	E-3	Biphenyl	4.8	µg/kg
2007-1	E-3	Chrysene	10.7	µg/kg
2007-1	E-3	Fluoranthene	8.150	µg/kg
2007-1	E-3	Heptachlor	690	ng/kg
2007-1	E-3	Hexachlorobenzene	560	ng/kg
2007-1	E-3	Naphthalene	24.300	µg/kg
2007-1	E-3	p,p-DDE	280	ng/kg
2007-1	E-3	PCB 101	1600	ng/kg
2007-1	E-3	PCB 105	410	ng/kg
2007-1	E-3	PCB 110	1300	ng/kg
2007-1	E-3	PCB 118	1100	ng/kg
2007-1	E-3	PCB 123	41	ng/kg
2007-1	E-3	PCB 128	160	ng/kg
2007-1	E-3	PCB 138	980	ng/kg
2007-1	E-3	PCB 149	790	ng/kg
2007-1	E-3	PCB 151	320	ng/kg
2007-1	E-3	PCB 153/168	390	ng/kg
2007-1	E-3	PCB 156	120	ng/kg
2007-1	E-3	PCB 158	160	ng/kg
2007-1	E-3	PCB 167	110	ng/kg
2007-1	E-3	PCB 170	120	ng/kg

Appendix B.2 *continued*

Date	Station	Parameter	Value	Units
2007-1	E-3	PCB 177	100	ng/kg
2007-1	E-3	PCB 180	270	ng/kg
2007-1	E-3	PCB 187	170	ng/kg
2007-1	E-3	PCB 201	19	ng/kg
2007-1	E-3	PCB 206	92	ng/kg
2007-1	E-3	PCB 44	310	ng/kg
2007-1	E-3	PCB 49	280	ng/kg
2007-1	E-3	PCB 52	870	ng/kg
2007-1	E-3	PCB 66	330	ng/kg
2007-1	E-3	PCB 70	350	ng/kg
2007-1	E-3	PCB 74	140	ng/kg
2007-1	E-3	PCB 87	780	ng/kg
2007-1	E-3	PCB 99	480	ng/kg
2007-1	E-3	Phenanthrene	8.35	µg/kg
2007-1	E-3	Pyrene	20.900	µg/kg
2007-1	E-5	1-methylnaphthalene	7.1	µg/kg
2007-1	E-5	2,6-dimethylnaphthalene	8.800	µg/kg
2007-1	E-5	2-methylnaphthalene	27	µg/kg
2007-1	E-5	Benzo[A]anthracene	12.800	µg/kg
2007-1	E-5	Biphenyl	11.900	µg/kg
2007-1	E-5	Fluoranthene	6.4	µg/kg
2007-1	E-5	Hexachlorobenzene	300	ng/kg
2007-1	E-5	Naphthalene	24.800	µg/kg
2007-1	E-5	p,p-DDE	220	ng/kg
2007-1	E-5	PCB 110	100	ng/kg
2007-1	E-5	Phenanthrene	18.400	µg/kg
2007-1	E-5	Pyrene	28.600	µg/kg
2007-1	E-7	1-methylnaphthalene	9.75	µg/kg
2007-1	E-7	1-methylphenanthrene	3.5	µg/kg
2007-1	E-7	2,6-dimethylnaphthalene	10.800	µg/kg
2007-1	E-7	2-methylnaphthalene	32.5	µg/kg
2007-1	E-7	Anthracene	2.05	µg/kg
2007-1	E-7	Benzo[A]anthracene	13.400	µg/kg
2007-1	E-7	Biphenyl	11.5	µg/kg
2007-1	E-7	Chrysene	6.3	µg/kg
2007-1	E-7	Fluoranthene	5.8	µg/kg
2007-1	E-7	Naphthalene	33	µg/kg
2007-1	E-7	p,p-DDE	340	ng/kg
2007-1	E-7	PCB 110	55	ng/kg
2007-1	E-7	PCB 153/168	28	ng/kg
2007-1	E-7	Phenanthrene	9.2	µg/kg
2007-1	E-7	Pyrene	13.5	µg/kg

Appendix B.2 *continued*

Date	Station	Parameter	Value	Units
2007-1	E-8	1-methylnaphthalene	6.25	µg/kg
2007-1	E-8	2,6-dimethylnaphthalene	7.4	µg/kg
2007-1	E-8	2-methylnaphthalene	24.800	µg/kg
2007-1	E-8	Anthracene	1.3	µg/kg
2007-1	E-8	Benzo[A]anthracene	13	µg/kg
2007-1	E-8	Biphenyl	10.7	µg/kg
2007-1	E-8	Hexachlorobenzene	160	ng/kg
2007-1	E-8	Naphthalene	24.600	µg/kg
2007-1	E-8	p,p-DDE	190	ng/kg
2007-1	E-8	Phenanthrene	7.4	µg/kg
2007-1	E-8	Pyrene	6.7	µg/kg
2007-1	E-9	1-methylnaphthalene	6.25	µg/kg
2007-1	E-9	2,6-dimethylnaphthalene	5.9	µg/kg
2007-1	E-9	2-methylnaphthalene	19.900	µg/kg
2007-1	E-9	Anthracene	1.45	µg/kg
2007-1	E-9	Benzo[A]anthracene	11.6	µg/kg
2007-1	E-9	Biphenyl	10.1	µg/kg
2007-1	E-9	Hexachlorobenzene	65	ng/kg
2007-1	E-9	Naphthalene	21	µg/kg
2007-1	E-9	p,p-DDE	100	ng/kg
2007-1	E-9	PCB 105	42	ng/kg
2007-1	E-9	PCB 110	190	ng/kg
2007-1	E-9	PCB 118	120	ng/kg
2007-1	E-9	PCB 138	95	ng/kg
2007-1	E-9	PCB 149	75	ng/kg
2007-1	E-9	PCB 153/168	34	ng/kg
2007-1	E-9	PCB 180	16	ng/kg
2007-1	E-9	PCB 52	120	ng/kg
2007-1	E-9	PCB 70	39	ng/kg
2007-1	E-9	PCB 87	120	ng/kg
2007-1	E-9	PCB 99	130	ng/kg
2007-1	E-9	Phenanthrene	5.75	µg/kg
2007-1	E-9	Pyrene	8.95	µg/kg
2007-3	B-10	1-methylnaphthalene	2.7	µg/kg
2007-3	B-10	2-methylnaphthalene	5.8	µg/kg
2007-3	B-10	Fluoranthene	3.7	µg/kg
2007-3	B-10	Naphthalene	18.600	µg/kg
2007-3	B-11	1-methylnaphthalene	37.100	µg/kg
2007-3	B-11	2,6-dimethylnaphthalene	14.2	µg/kg
2007-3	B-11	2-methylnaphthalene	46	µg/kg
2007-3	B-11	Acenaphthylene	8.7	µg/kg
2007-3	B-11	Biphenyl	31.300	µg/kg

Appendix B.2 *continued*

Date	Station	Parameter	Value	Units
2007-3	B-11	Hexachlorobenzene	270	ng/kg
2007-3	B-11	Naphthalene	126	µg/kg
2007-3	B-11	Phenanthrene	15.7	µg/kg
2007-3	B-11	Pyrene	22.400	µg/kg
2007-3	B-12	2-methylnaphthalene	6.5	µg/kg
2007-3	B-12	Hexachlorobenzene	610	ng/kg
2007-3	B-12	Naphthalene	21.300	µg/kg
2007-3	B-8	1-methylnaphthalene	4.9	µg/kg
2007-3	B-8	2-methylnaphthalene	10	µg/kg
2007-3	B-8	Fluoranthene	9.2	µg/kg
2007-3	B-8	Naphthalene	30.900	µg/kg
2007-3	B-8	Phenanthrene	13.5	µg/kg
2007-3	B-9	1-methylnaphthalene	3.1	µg/kg
2007-3	B-9	2-methylnaphthalene	5.7	µg/kg
2007-3	B-9	Biphenyl	9.900	µg/kg
2007-3	B-9	Naphthalene	20.600	µg/kg
2007-3	B-9	Phenanthrene	5.2	µg/kg
2007-3	E-1	Biphenyl	12	µg/kg
2007-3	E-1	Naphthalene	23.100	µg/kg
2007-3	E-1	p,p-DDE	370	ng/kg
2007-3	E-1	PCB 149	250	ng/kg
2007-3	E-1	Phenanthrene	25.300	µg/kg
2007-3	E-11	Naphthalene	23.7	µg/kg
2007-3	E-14	2-methylnaphthalene	8.6	µg/kg
2007-3	E-14	Naphthalene	27.300	µg/kg
2007-3	E-15	1-methylnaphthalene	10.400	µg/kg
2007-3	E-15	2-methylnaphthalene	18.400	µg/kg
2007-3	E-15	Naphthalene	50.200	µg/kg
2007-3	E-17	2-methylnaphthalene	9.900	µg/kg
2007-3	E-17	Naphthalene	25.400	µg/kg
2007-3	E-17	p,p-DDE	410	ng/kg
2007-3	E-19	2-methylnaphthalene	8.800	µg/kg
2007-3	E-19	Naphthalene	28.100	µg/kg
2007-3	E-19	p,p-DDE	420	ng/kg
2007-3	E-2	2-methylnaphthalene	15.400	µg/kg
2007-3	E-2	Naphthalene	45.700	µg/kg
2007-3	E-2	p,p-DDE	440	ng/kg
2007-3	E-2	PCB 110	200	ng/kg
2007-3	E-20	Naphthalene	18.600	µg/kg
2007-3	E-20	p,p-DDE	270	ng/kg
2007-3	E-21	2-methylnaphthalene	8.400	µg/kg
2007-3	E-21	Naphthalene	33.400	µg/kg

Appendix B.2 *continued*

Date	Station	Parameter	Value	Units
2007-3	E-21	p,p-DDE	340	ng/kg
2007-3	E-23	2-methylnaphthalene	9.6	µg/kg
2007-3	E-23	Naphthalene	28.5	µg/kg
2007-3	E-23	p,p-DDE	500	ng/kg
2007-3	E-25	2-methylnaphthalene	7.1	µg/kg
2007-3	E-25	Naphthalene	23.5	µg/kg
2007-3	E-25	Phenanthrene	13.7	µg/kg
2007-3	E-26	1-methylnaphthalene	3.3	µg/kg
2007-3	E-26	2-methylnaphthalene	6.9	µg/kg
2007-3	E-26	Hexachlorobenzene	390	ng/kg
2007-3	E-26	Naphthalene	20	µg/kg
2007-3	E-3	Hexachlorobenzene	240	ng/kg
2007-3	E-3	Naphthalene	25.600	µg/kg
2007-3	E-3	PCB 101	480	ng/kg
2007-3	E-5	2-methylnaphthalene	6.5	µg/kg
2007-3	E-5	Biphenyl	16.800	µg/kg
2007-3	E-5	Naphthalene	20.800	µg/kg
2007-3	E-7	2-methylnaphthalene	7.4	µg/kg
2007-3	E-7	Biphenyl	15.1	µg/kg
2007-3	E-7	Naphthalene	23.2	µg/kg
2007-3	E-7	p,p-DDE	450	ng/kg
2007-3	E-8	Biphenyl	9.2	µg/kg
2007-3	E-8	Naphthalene	21.400	µg/kg
2007-3	E-9	2-methylnaphthalene	10.300	µg/kg
2007-3	E-9	Naphthalene	32.300	µg/kg

Appendix B.3

PLOO sediment statistics January 2007.

Station	Mean (mm)	Mean (phi)	SD (phi)	Median (phi)	Skewness (phi)	Kurtosis (phi)	Coarse (%)	Sand (%)	Silt (%)	Clay (%)	Sediment Observations
North reference stations											
B11	0.053	4.2	1.9	3.8	0.3	0.9	2.1	53.0	40.1	4.9	Shell hash, small rocks
B8	0.040	4.6	1.6	4.3	0.4	0.9	0.0	41.6	54.6	3.8	
B12	0.063	4.0	1.8	3.3	0.5	0.9	0.0	63.9	33.2	2.9	Shell hash, small rocks
B9	0.051	4.3	1.7	3.7	0.5	0.9	0.0	56.8	39.8	3.4	Mud, pea gravel, small rocks
B10	0.067	3.9	1.5	3.2	0.7	1.3	0.0	70.6	26.9	2.5	Shell hash, small rocks
Stations north of the outfall											
E19	0.050	4.3	1.5	3.9	0.4	1.1	0.0	53.4	44.0	2.6	
E20	0.056	4.2	1.5	3.7	0.4	1.1	1.0	60.1	36.0	2.9	Shell hash
E23	0.058	4.1	1.4	3.7	0.4	1.2	0.0	60.3	37.4	2.2	Shell hash
E25	0.056	4.1	1.5	3.7	0.5	1.1	0.0	60.3	37.3	2.5	Shell hash
E26	0.051	4.3	1.5	3.8	0.4	1.0	0.0	55.7	41.3	2.9	Shell hash
E21	0.061	4.0	1.5	3.6	0.5	1.2	0.0	66.3	31.3	2.4	
Near outfall stations											
E11	0.071	3.8	1.3	3.4	0.5	1.4	0.0	68.9	29.2	2.0	Shell hash
E14	0.069	3.9	1.4	3.4	0.5	1.4	0.0	69.0	28.8	2.2	Coarse black sand, shell hash
E17	0.065	3.9	1.4	3.6	0.5	1.2	0.0	67.6	30.3	2.1	Shell hash
E15	0.064	4.0	1.5	3.4	0.6	1.2	0.0	66.8	30.8	2.4	Coarse black sand, shell hash
Stations south of the outfall											
E1	0.060	4.1	2.3	3.6	0.1	1.4	5.7	52.8	38.1	3.5	Coarse sand, shell hash, small rocks
E7	0.056	4.1	1.4	3.8	0.4	1.1	0.0	58.1	39.6	2.3	
E2	0.116	3.1	1.6	4.1	-0.8	0.9	8.6	32.9	58.5	0.0	
E5	0.063	4.0	1.5	3.5	0.5	1.2	0.0	64.2	33.4	2.5	Shell hash
E8	0.068	3.9	1.4	3.5	0.5	1.3	0.0	66.0	32.0	2.0	
E3	0.066	3.9	1.8	3.2	0.5	0.9	1.1	62.6	33.4	2.9	Coarse sand, shell hash, small rocks
E9	0.150	2.7	1.9	4.0	-0.9	0.6	17.9	25.0	57.1	0.0	Coarse black sand, shell hash

Appendix B.3 *continued*

PLOO sediment statistics July 2007.

Station	Mean (mm)	Mean (phi)	SD (phi)	Median (phi)	Skewness (phi)	Kurtosis (phi)	Coarse (%)	Sand (%)	Silt (%)	Clay (%)	Sediment Observations
North reference stations											
B11	0.051	4.3	1.7	3.9	0.4	0.9	1.1	53.0	42.3	3.6	Mud balls, shell hash
B8	0.043	4.5	1.5	4.2	0.4	1.0	0.0	44.7	52.0	3.3	
B12	0.067	3.9	1.8	3.3	0.5	1.0	2.3	63.9	30.9	2.9	Mud balls, pea gravel, shell hash
B9	0.051	4.3	1.6	3.7	0.5	0.9	0.0	56.9	40.0	3.1	
B10	0.068	3.9	1.5	3.2	0.6	1.3	0.0	70.3	27.3	2.4	Shell hash
Stations north of the outfall											
E19	0.048	4.4	1.5	3.9	0.4	1.1	0.0	52.2	44.5	3.3	Shell hash
E20	0.063	4.0	1.4	3.6	0.5	1.3	0.0	64.2	33.4	2.4	Shell hash
E23	0.052	4.3	1.6	3.7	0.5	1.0	0.0	57.7	39.4	2.9	Shell hash
E25	0.059	4.1	1.5	3.6	0.5	1.2	0.0	61.8	35.6	2.6	Shell hash
E26	0.052	4.3	1.5	3.8	0.5	1.0	0.0	56.8	40.5	2.8	Shell hash
E21	0.061	4.0	1.5	3.4	0.6	1.2	0.0	66.5	30.9	2.6	
Near outfall stations											
E11	0.077	3.7	1.2	3.4	0.5	1.5	0.0	71.1	27.1	1.9	Coarse Black sand, shell hash
E14	0.076	3.7	1.3	3.3	0.5	1.5	0.0	71.9	26.1	2.1	Coarse Black sand, shell hash
E17	0.067	3.9	1.4	3.5	0.5	1.3	0.0	66.9	30.9	2.1	Shell hash
E15	0.064	4.0	1.5	3.5	0.5	1.2	0.0	68.5	29.1	2.4	Coarse Black sand, shell hash
Stations south of the outfall											
E1	0.062	4.0	1.6	3.5	0.5	1.0	0.0	61.6	35.8	2.7	Shell hash
E7	0.054	4.2	1.5	3.8	0.4	1.1	0.0	57.0	40.6	2.4	Shell hash
E2	0.111	3.2	1.5	4.1	-0.9	1.0	7.2	30.9	62.0	0.0	Coarse sand, pea gravel, rocks
E5	0.066	3.9	1.4	3.6	0.4	1.2	0.0	66.7	31.0	2.2	Shell hash
E8	0.066	3.9	1.4	3.5	0.5	1.3	0.0	66.6	31.2	2.2	Shell hash
E3	0.175	2.5	1.6	2.6	-0.2	0.8	9.1	55.9	35.1	0.0	Coarse sand, pea gravel, rocks, shell hash
E9	0.055	4.2	1.6	3.6	0.5	1.0	0.0	61.1	35.9	3.0	Coarse Black sand, shell hash

Appendix C

Supporting Data

2007 PLOO Stations

Demersal Fishes and Megabenthic Invertebrates

Appendix C.1

Summary of demersal fish species captured during 2007 at PLOO stations. Data are number of fish (n), biomass (BM, wet weight, kg), minimum (Min), maximum (Max), and mean length (cm). Taxonomic arrangement and scientific names are of Eschmeyer and Herald (1998) and Allen (2005).*

				Length		
Taxon/Species	**Common name**	**n**	**BM**	**Min**	**Max**	**Mean**
MYXNINFORMES						
Myxinidae						
Merlucciusproductus	Pacific hake	2	0	20	29	25
RAJIFORMES						
Rajidae						
Raja inornata	California skate	3	2	26	52	41
CHIMAERIFORMES						
Chimaeridae						
Hydrolagus colliei	Spotted ratfish	4	1	34	42	39
TORPEDINIFORMES						
Torpedinidae						
Torpedo californica	Pacific electric ray	1	0	22	22	22
AULOPIFORMES						
Synodontidae						
Synodus lucioceps	California lizardfish	5	0	13	23	19
OSMERIFORMES						
Argentinidae						
Argentina sialis	Pacific argentine	1	0	7	7	7
OPHIDIIFORMES						
Ophidiidae						
Chilara taylori	Spotted cuskeel	11	0	15	22	17
BATRACHOIDIFORMES						
Batrachoididae						
Porichthys notatus	Plainfin midshipman	79	2	5	15	10
Sebastes goodei	Chilipepper rockfish	1	0	12	12	12
SCORPAENIFORMES						
Scorpaenidae						
Scorpaena guttata	California scorpionfish	21	7	15	27	21
Sebastes chlorostictus	Greenspotted rockfish	1	0	13	13	13
Sebastes elongatus	Greenstriped rockfish	11	0	4	14	11
Sebastes eos	Pink rockfish	1	0	7	7	7
Sebastes hopkinsi	Squarespot rockfish	1	0	10	10	10
Sebastes rosenblatti	Greenblotched rockfish	6	0	9	17	12
Sebastes rubrivinctus	Flag rockfish	3	0	6	9	8
Sebastes saxicola	Stripetail rockfish	12	0	8	11	9
Sebastes semicinctus	Halfbanded rockfish	234	5	6	12	10
Sebastes sp	Unidentified rockfish	4	0	4	10	8
Hexagrammidae						
Zaniolepis frenata	Shortspine combfish	96	3	7	18	13
Zaniolepis latipinnis	Longspine combfish	208	5	8	16	12
Cottidae						
Icelinus fimbriatus	Fringed sculpin	1	0	15	15	15
Chitonotus pugetensis	Roughback sculpin	6	0	8	10	9
Icelinus quadriseriatus	Yellowchin sculpin	58	0	5	11	7
Icelinus tenuis	Spotfin sculpin	15	0	7	10	9

Appendix C.1 *continued*

Taxon/Species	Common name	n	BM	Length Min	Max	Mean
Agonidae						
Odontopyxis trispinosa	Pygmy poacher	14	0	8	14	13
Xeneretmus latifrons	Blacktip poacher	4	0	13	14	13
PERCIFORMES						
Sciaenidae						
Genyonemus lineatus	White croaker	6	0	19	22	21
Embiotocidae						
Cymatogaster aggregata						
Zalembius rosaceus	Pink seaperch	83	1	4	14	7
Bathymasteridae						
Rathbunella hypoplecta	Bluespotted poacher	1	0	12	12	12
Zoarcidae						
Lycodopsis pacifica	Blackbelly eelpout	11	0	17	26	21
Stichaeidae						
Plectobranchus evides	Calico rockfish	1	0	3	3	3
Scombridae						
PLEURONECTIFORMES	Unidentified flatfish	1	0	4	4	4
Paralichthyidae						
Citharichthys sordidus	Pacific sanddab	1100	29	4	24	10
Hippoglossina stomata	Bigmouth sole	27	2	13	23	16
Pleuronectidae						
Eopsetta exilis	Slender sole	29	0	9	15	13
Microstomus pacificus	Dover sole	189	6	5	18	13
Parophrys vetulus	English sole	115	10	11	26	17
Pleuronichthys verticalis	Hornyhead turbot	50	5	11	20	15
Cynoglossidae						
Symphurus atricauda	California tonguefish	38	1	10	17	14

* Eschmeyer, W. N. and E.S. Herald. (1998). A Field Guide to Pacific Coast Fishes of North America. Houghton and Mifflin Company, New York. 336 p.

Allen, M.J. 2005. The check list of trawl-caught fishes for Southern California from depths of 2–265 m. Southern California Research Project, Westminster, CA.

Appendix C.2

Summary of total abundance by species and station for demersal fish at the Point Loma Ocean Outfall trawl stations during 2007. Species abundance value is cumulative for 6 stations.

	February 2007						
NAME	SD7	SD8	SD10	SD12	SD13	SD14	Species abundance by survey
Pacific sanddab	107	103	85	98	23	59	475
Longspine combfish	15	1	12	33	50	46	157
English sole	26	24	13	10	25		98
Halfbanded rockfish	31	16	37	2	6	4	96
Dover sole	1	13	6	25	3	29	77
Pink seaperch	19	7	4	33	6	2	71
Yellowchin sculpin	24	2	7	2	3	16	54
Shortspine combfish	9	19	5	11		1	45
Hornyhead turbot	4	1	8	10	10	4	37
Plainfin midshipman	13	3	2	3	4	5	30
California tonguefish	6	6	5	3	1	4	25
California scorpionfish		1	7	10	2		20
Bigmouth sole	3	2	1	9	3	1	19
Spotfin sculpin	4	4					8
Stripetail rockfish					1	7	8
Roughback sculpin	1	4				1	6
California lizardfish		1			4		5
Greenstriped rockfish		3	1			1	5
Greenblotched rockfish		1			3		4
Blacktip poacher		3					3
Flag rockfish	1		1				2
Pacific hake	1	1					2
Unidentified rockfish	1	1					2
California skate				1			1
Fringed sculpin		1					1
Greenspotted rockfish			1				1
Pacific argentine	1						1
Pacific electric ray			1				1
Pygmy poacher		1					1
Unidentified flatfish	1						1
White croaker		1					1
Winter total	268	219	196	250	144	180	1257

Appendix C.2 *continued*

	July 2007						
NAME	**SD7**	**SD8**	**SD10**	**SD12**	**SD13**	**SD14**	**Species abundance by survey**
Pacific sanddab	82	116	106	81	88	152	625
Halfbanded rockfish	9	20	80	7	7	15	138
Dover sole	5	11	19	44	19	14	112
Longspine combfish		6	5	16	11	13	51
Shortspine combfish	3	16	7	16	5	4	51
Plainfin midshipman		2	5	12	11	19	49
Slender sole	1	2	3	12	6	5	29
English sole	1	4	5	2	2	3	17
California tonguefish	4	4	5				13
Hornyhead turbot		3	3	1	5	1	13
Pygmy poacher		1		1	1	10	13
Pink seaperch		3	4	1	3	1	12
Blackbelly eelpout			1	9		1	11
Spotted cuskeel	4	1	2	4			11
Bigmouth sole	1	3	2		1	1	8
Spotfin sculpin		3	3		1		7
Greenstriped rockfish	2	1	1			2	6
White croaker		5					5
Spotted ratfish	2		1	1			4
Stripetail rockfish			1		1	2	4
Yellowchin sculpin	4						4
California skate			2				2
Greenblotched rockfish						2	2
Unidentified rockfish		1	1				2
Blacktip poacher		1					1
Bluespotted poacher						1	1
Calico rockfish				1			1
California scorpionfish			1				1
Chilipepper rockfish						1	1
Flag rockfish						1	1
Pink rockfish						1	1
Squarespot rockfish						1	1
Summer total	118	203	257	208	161	250	1197
Annual total	**386**	**422**	**453**	**458**	**305**	**430**	**2454**

Appendix C.3

Summary of biomass (kg) by species and station for demersal fish at the Point Loma Ocean Outfall trawl stations during 2007. Species biomass value is cumulative for 6 stations.

	February 2007						
NAME	SD7	SD8	SD10	SD12	SD13	SD14	Biomass by survey
Pacific sanddab	2.4	2.0	2.9	1.7	0.7	2.0	11.7
English sole	3.2	2.2	0.1	0.9	1.5		7.9
California scorpionfish		0.4	2.6	4.0	0.2		7.2
Hornyhead turbot	0.4	0.1	1.0	1.0	1.0	0.2	3.7
Longspine combfish	0.5	0.1	0.1	0.8	1.0	0.8	3.3
Dover sole	0.1	0.4	0.1	0.3	0.1	1.0	2.0
Halfbanded rockfish	0.3	0.4	0.9	0.1	0.1	0.1	1.9
Shortspine combfish	0.2	0.6	0.1	0.1		0.1	1.1
Bigmouth sole	0.2	0.1	0.1	0.4	0.1	0.1	1.0
Pink seaperch	0.3	0.1	0.1	0.1	0.1	0.1	0.8
California skate				0.8			0.8
California tonguefish	0.2	0.2	0.1	0.1	0.1	0.1	0.8
Plainfin midshipman	0.2	0.1	0.1	0.1	0.1	0.1	0.7
Yellowchin sculpin	0.1	0.1	0.1	0.1	0.1	0.1	0.6
Pacific hake	0.2	0.2					0.4
Pacific electric ray			0.4				0.4
Greenstriped rockfish		0.1	0.1			0.1	0.3
Roughback sculpin	0.1	0.1				0.1	0.3
California lizardfish		0.1			0.1		0.2
Flag rockfish	0.1		0.1				0.2
Greenblotched rockfish		0.1			0.1		0.2
Spotfin sculpin	0.1	0.1					0.2
Stripetail rockfish					0.1	0.1	0.2
Unidentified rockfish	0.1	0.1					0.2
White croaker		0.2					0.2
Blacktip poacher		0.1					0.1
Fringed sculpin		0.1					0.1
Greenspotted rockfish			0.1				0.1
Pacific argentine	0.1						0.1
Pygmy poacher		0.1					0.1
Unidentified flatfish	0.1						0.1
Winter total	8.9	8.1	9.0	10.5	5.4	5.0	46.9

Appendix C.3 *continued*

NAME	SD7	SD8	SD10	SD12	SD13	SD14	Biomass by survey
			July 2007				
Pacific sanddab	1.4	1.8	2.3	1.0	1.5	9.0	17.0
Dover sole	0.4	0.4	0.7	1.8	0.7	0.4	4.4
Halfbanded rockfish	0.2	0.4	1.5	0.1	0.1	0.3	2.6
English sole	0.1	0.3	0.5	0.1	0.3	0.3	1.6
Shortspine combfish	0.1	0.5	0.2	0.3	0.2	0.1	1.4
Hornyhead turbot		0.2	0.4	0.1	0.5	0.1	1.3
Spotted ratfish	0.6		0.3	0.4			1.3
Longspine combfish		0.2	0.1	0.4	0.3	0.3	1.3
California skate			1.0				1.0
Plainfin midshipman		0.1	0.1	0.3	0.1	0.3	0.9
Slender sole	0.1	0.1	0.1	0.4	0.1	0.1	0.9
Bigmouth sole	0.1	0.3	0.2		0.1	0.1	0.8
White croaker		0.6					0.6
Blackbelly eelpout			0.1	0.3		0.1	0.5
Pink seaperch		0.1	0.1	0.1	0.1	0.1	0.5
California tonguefish	0.1	0.1	0.2				0.4
Greenstriped rockfish	0.1	0.1	0.1			0.1	0.4
Pygmy poacher		0.1		0.1	0.1	0.1	0.4
Spotted cuskeel	0.1	0.1	0.1	0.1			0.4
Spotfin sculpin		0.1	0.1		0.1		0.3
Stripetail rockfish			0.1		0.1	0.1	0.3
Unidentified rockfish		0.1	0.1				0.2
Blacktip poacher		0.1					0.1
Bluespotted poacher						0.1	0.1
Calico rockfish				0.1			0.1
California scorpionfish			0.1				0.1
Chilipepper rockfish						0.1	0.1
Flag rockfish						0.1	0.1
Greenblotched rockfish						0.1	0.1
Pink rockfish						0.1	0.1
Squarespot rockfish						0.1	0.1
Yellowchin sculpin	0.1						0.1
Summer total	3.4	5.7	8.4	5.6	4.3	12.1	39.5
Annual total	**12.3**	**13.8**	**17.4**	**16.1**	**9.7**	**17.1**	**86.4**

Appendix C.4

List of megabenthic invertebrate taxa captured during 2007 at PLOO stations. Data are number of individuals (n). Taxonomic arrangement from SCAMIT 2001.*

Taxon/Species					N
PORIFERA					**3**
	Demospongiae				
		Hadromerida			
			Suberitidae		
				Suberites sp	3
CNIDARIA					
	ANTHOZOA				
		Alcyonacea			
			Muriceidae		
				Thesea sp B	6
		Pennatulacea			
			Virgulariidae		
				Acanthoptilum sp	976
				Stylatula elongata	1
		Actiniaria			
			Metridiidae		
				Metridium farcimen	5
MOLLUSCA					
	GASTROPODA				
		Neotaeniglossa			
			Naticidae		
				Euspira draconis	1
		Neogastropoda			
			Ovulidae		
				Neosimnia barbarensis	5
			Fasciolariidae		
				Fusinus barbarensis	1
			Turridae		
				Antiplanes catalinae	1
			Cancellariidae		
				Calliostoma turbinum	4
		Cephalaspidea			
			Philinidae		
				Philine alba	3
		Notaspidea			
			Pleurobranchidae		
				Pleurobranchaea californica	4
		Nudibranchia			
			Platydordidae		
				Platydoris macfarlandi	1
			Onchidorididae		
				Acanthodoris brunnea	2
			Arminidae		
				Armina californica	5
	CEPHALOPODA				
		Sepiolida			
			Sepiolidae		
				Rossia pacifica	1

Appendix C.4 *continued*

Taxon/Species	N
Octopoda	
Octopodidae	
Octopus rubescens	7
ARTHROPODA	
MALACOSTRACA	
Stomatopoda	
Squillidae	
Schmittius politus	1
Decapoda	
Sicyoniidae	
Sicyonia ingentis	26
Crangonidae	
Neocrangon zacae	2
Diogenidae	
Paguristes bakeri	1
Paguristes turgidus	1
Paguristes ulreyi	1
Majidae	
Podochela lobifrons	3
Calappidae	
Platymera gaudichaudii	5
Isopoda	
Cymothoidae	
Elthusa vulgaris	1
ECHINODERMATA	
CRINOIDEA	
Comatulida	
Antedonidae	
Florometra serratissima	4
ASTEROIDEA	
Paxillosida	
Luidiidae	
Luidia armata	11
Luidia asthenosoma	5
Luidia foliolata	74
Luidia sp	1
Astropectinidae	
Astropecten verrilli	35
Valvatida	
Odontasteridae	
Ondontaster crassus	1
OPHIUROIDEA	
Ophiurida	
Ophiotricidae	
Ophiothrix spiculata	12
Ophiuridae	
Ophiura luetkenii	28

Appendix C.4 *continued*

Taxon/Species	N
ECHINOIDEA	
Temnopleuroida	
Toxopneustidae	
Lytechinus pictus	21526
Echinoida	
Strongylocentrotidae	
Allocentrotus fragilis	531
Spatangoida	
Spatangidae	
Spatangus californicus	30
HOLOTHURIODEA	
Aspidochirotida	
Stichopodidae	
Parastichopus californicus	50
CHORDATA	
ASCIDIACEA	
Stolidobranchiata	
Pyuridae	
Halocynthia igaboja	1

*[SCAMIT] The Southern California Association of Marine Invertebrate Taxonomists. (2001). A taxonomic listing of soft bottom marco- and megabenthic invertebrates from infaunal and epibenthic monitoring programs in the Soutern California Bight; Edition 4. SCAMIT. San Pedro, CA.

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Appendix C.5

Summary of total abundance by species and station for megabenthic invertebrates at the Point Loma Ocean Outfall trawl stations during 2007. Species abundance value is cumulative for 6 stations.

	February 2007						
NAME	**SD7**	**SD8**	**SD10**	**SD12**	**SD13**	**SD14**	**Species abundance by survey**
Lytechinus pictus	2400	2850	2300	3400	925	90	11965
Acanthoptilum sp			20	600	10	3	633
Luidia foliolata	1	15	9	3	12	16	56
Allocentrotus fragilis		4		12	1	5	22
Parastichopus californicus		11	2	4	2		19
Spatangus californicus		5		1	9	4	19
Ophiothrix spiculata		1		10			11
Sicyonia ingentis		2			3	5	10
Astropecten verrilli	1	1	2	1			5
Metridium farcimen		4		1			5
Ophiura luetkenii	3			1		1	5
Thesea sp B	2	1	1				4
Luidia asthenosoma	3						3
PORIFERA		3					3
Platymera gaudichaudii	1	1			1		3
Florometra serratissima	2						2
Octopus rubescens	1	1					2
Podochela lobifrons		2					2
Suberites sp		1	1				2
Fusinus barbarensis	1						1
Halocynthia igaboja		1					1
Luidia sp	1						1
Ondontaster crassus		1					1
Paguristes bakeri		1					1
Paguristes ulreyi			1				1
Platydoris macfarlandi			1				1
Pleurobranchaea californica	1						1
Rossia pacifica			1				1
Schmittius politus					1		1
Winter total	2417	2905	2338	4033	964	124	12781

Appendix C.5 *continued*

July 2007

NAME	SD7	SD8	SD10	SD12	SD13	SD14	Species abundance by survey
Lytechinus pictus	3180	2378	3131		542	330	9561
Allocentrotus fragilis	1	62	7	19	180	240	509
Acanthoptilum sp		1	3	238	53	48	343
Parastichopus californicus	9	12	3	3	3	1	31
Astropecten verrilli	7	1	10	6	3	3	30
Ophiura luetkenii	5		3	2	7	6	23
Luidia foliolata	3	4	6		2	3	18
Sicyonia ingentis	13			1		2	16
Luidia armata	1			9	1		11
Spatangus californicus		2	3	1	2	3	11
Armina californica				4	1		5
Neosimnia barbarensis					1	4	5
Octopus rubescens			2	1	1	1	5
Calliostoma turbinum			1	3			4
Philine alba	2					1	3
Pleurobranchaea californica	1	1		1			3
Acanthodoris brunnea				2			2
Florometra serratissima	1		1				2
Luidia asthenosoma			1			1	2
Neocrangon zacae						2	2
Platymera gaudichaudii	1		1				2
Thesea sp B			1		1		2
Antiplanes catalinae				1			1
Elthusa vulgaris			1				1
Euspira draconis				1			1
Ophiothrix spiculata			1				1
Paguristes turgidus	1						1
Podochela lobifrons		1					1
Stylatula elongata				1			1
Suberites sp				1			1
Summer total	3225	2462	3175	294	797	645	10598
Annual total	**5642**	**5367**	**5513**	**4327**	**1761**	**769**	**23379**

Appendix D

Supporting Data

2007 PLOO Stations

Bioaccumulation of Contaminants in Fish Tissues

Appendix D.1

Summary of fishes used for each composite sample for the PLOO monitoring program during October 2007.

			Length (cm, size class)				Weight (g)		
Station	**Rep**	**Species**	**N**	**min**	**max**	**mean**	**min**	**max**	**mean**
RF1	1	Vermilion rockfish	3	27	32	29	449	754	592
RF1	2	Vermilion rockfish	3	24	31	28	262	690	531
RF1	3	Copper rockfish	3	31	32	32	745	1031	873
RF2	1	Greenblotched rockfish	3	152	273	231	19	23	21
RF2	2	Greenblotched rockfish	3	18	31	24	136	665	348
RF2	3	Mixed rockfish	3	16	29	23	77	589	322
Zone1	1	Pacific sanddab	3	15	21	18	76	150	123
Zone1	2	Pacific sanddab	8	13	23	17	31	204	77
Zone1	3	English sole	9	16	22	18	67	146	89
Zone2	1	Pacific sanddab	5	17	20	18	76	113	92
Zone2	2	Pacific sanddab	5	16	20	18	54	122	86
Zone2	3	Pacific sanddab	5	16	20	18	65	127	77
Zone3	1	Pacific sanddab	6	17	19	18	68	99	81
Zone3	2	Pacific sanddab	4	17	20	18	72	128	95
Zone3	3	Pacific sanddab	3	15	24	18	43	232	114
Zone4	1	Pacific sanddab	3	18	22	20	98	179	130
Zone4	2	Pacific sanddab	4	16	22	18	80	190	120
Zone4	3	Pacific sanddab	3	16	22	19	68	157	109

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Appendix D.2

Constituents and method detection limits (MDL) for fish tissue samples analyzed for the PLOO monitoring program during October 2007.

Parameter	MDL Liver	MDL Muscle	Parameter	MDL Liver	MDL Muscle
Metals (ppm)					
Aluminum	0.580	0.580	Lead	0.300	0.300
Antimony	0.480	0.480	Manganese	0.007	0.007
Arsenic	0.380	0.380	Mercury	0.030	0.030
Barium	0.007	0.007	Nickel	0.094	0.094
Beryllium	0.003	0.003	Selenium	0.060	0.060
Cadmium	0.029	0.029	Silver	0.057	0.057
Chromium	0.080	0.080	Thallium	0.850	0.850
Copper	0.068	0.068	Tin	0.240	0.240
Iron	0.096	0.096	Zinc	0.049	0.049
Chlorinated Pesticides (ppb)					
Aldrin	*	6.67	Hexachlorobenzene	13.30	1.33
Alpha (cis) Chlordane	13.30	2.00	Mirex	13.30	1.33
Alpha Endosulfan	167.00	33.00	o,p-DDD	13.30	1.33
BHC, Alpha isomer	33.30	2.00	o,p-DDE	13.30	1.33
BHC, Beta isomer	13.30	2.00	o,p-DDT	13.30	1.33
BHC, Delta isomer	20.00	2.00	Oxychlordane	66.70	6.67
BHC, Gamma isomer	167.00	3.33	p,p-DDD	13.30	1.33
Cis Nonachlor	20.00	3.33	p,p-DDE	13.30	1.33
Dieldrin	13.30	1.33	p,-p-DDMU	13.30	1.33
Endrin	13.30	1.33	p,p-DDT	13.30	1.33
Gamma (trans) Chlordane	20.00	2.00	Toxaphene	3333.00	333.00
Heptachlor	33.30	3.33	Trans Nonachlor	13.30	2.00
Heptachlor epoxide	100.00	6.67			
PCB Congeners (ppb)					
PCB 18	33.3	1.33	PCB 126	13.3	1.33
PCB 28	13.3	1.33	PCB 128	13.3	1.33
PCB 37	13.3	1.33	PCB 138	13.3	*
PCB 44	13.3	1.33	PCB 149	13.3	1.33
PCB 49	13.3	1.33	PCB 151	13.3	1.33
PCB 52	13.3	1.33	PCB 153/168	13.3	*
PCB 66	13.3	1.33	PCB 156	13.3	1.33
PCB 70	13.3	1.33	PCB 157	13.3	1.33
PCB 74	13.3	1.33	PCB 158	13.3	1.33
PCB 77	13.3	1.33	PCB 167	13.3	1.33
PCB 81	13.3	1.33	PCB 169	13.3	1.33
PCB 87	13.3	1.33	PCB 170	13.3	1.33
PCB 99	13.3	1.33	PCB 177	13.3	1.33
PCB 101	13.3	1.33	PCB 180	13.3	1.33
PCB 105	13.3	1.33	PCB 183	13.3	1.33
PCB 110	13.3	1.33	PCB 187	13.3	1.33
PCB 114	13.3	1.33	PCB 189	13.3	1.33
PCB 118	13.3	1.33	PCB 194	13.3	1.33
PCB 119	13.3	1.33	PCB 201	13.3	1.33
PCB 123	13.3	1.33	PCB 206	13.3	1.33

* no MDL available for this parameter

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Appendix D.3

Summary of constituents that make up total DDT, total PCB, total chlordane, and total BHC in each sample collected as part of the PLOO monitoring program during October 2007.

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	RF1	1	Vermilion rockfish	Muscle	PCB 101	0.3	µg/kg
2007-4	RF1	1	Vermilion rockfish	Muscle	PCB 138	0.3	µg/kg
2007-4	RF1	1	Vermilion rockfish	Muscle	PCB 149	0.2	µg/kg
2007-4	RF1	1	Vermilion rockfish	Muscle	PCB 153/168	0.5	µg/kg
2007-4	RF1	1	Vermilion rockfish	Muscle	PCB 180	0.2	µg/kg
2007-4	RF1	1	Vermilion rockfish	Muscle	PCB 187	0.2	µg/kg
2007-4	RF1	1	Vermilion rockfish	Muscle	PCB 52	0.1	µg/kg
2007-4	RF1	1	Vermilion rockfish	Muscle	PCB 99	0.2	µg/kg
2007-4	RF1	1	Vermilion rockfish	Muscle	p,p-DDE	3.6	µg/kg
2007-4	RF1	2	Vermilion rockfish	Muscle	PCB 101	0.4	µg/kg
2007-4	RF1	2	Vermilion rockfish	Muscle	PCB 105	0.1	µg/kg
2007-4	RF1	2	Vermilion rockfish	Muscle	PCB 110	0.2	µg/kg
2007-4	RF1	2	Vermilion rockfish	Muscle	PCB 118	0.4	µg/kg
2007-4	RF1	2	Vermilion rockfish	Muscle	PCB 138	0.6	µg/kg
2007-4	RF1	2	Vermilion rockfish	Muscle	PCB 149	0.2	µg/kg
2007-4	RF1	2	Vermilion rockfish	Muscle	PCB 153/168	0.7	µg/kg
2007-4	RF1	2	Vermilion rockfish	Muscle	PCB 170	0.1	µg/kg
2007-4	RF1	2	Vermilion rockfish	Muscle	PCB 180	0.3	µg/kg
2007-4	RF1	2	Vermilion rockfish	Muscle	PCB 183	0.1	µg/kg
2007-4	RF1	2	Vermilion rockfish	Muscle	PCB 187	0.3	µg/kg
2007-4	RF1	2	Vermilion rockfish	Muscle	PCB 49	0.1	µg/kg
2007-4	RF1	2	Vermilion rockfish	Muscle	PCB 52	0.1	µg/kg
2007-4	RF1	2	Vermilion rockfish	Muscle	PCB 99	0.3	µg/kg
2007-4	RF1	2	Vermilion rockfish	Muscle	p,p-DDE	5.9	µg/kg
2007-4	RF1	3	Copper rockfish	Muscle	PCB 101	0.3	µg/kg
2007-4	RF1	3	Copper rockfish	Muscle	PCB 105	0.1	µg/kg
2007-4	RF1	3	Copper rockfish	Muscle	PCB 118	0.3	µg/kg
2007-4	RF1	3	Copper rockfish	Muscle	PCB 138	0.3	µg/kg
2007-4	RF1	3	Copper rockfish	Muscle	PCB 149	0.1	µg/kg
2007-4	RF1	3	Copper rockfish	Muscle	PCB 153/168	0.5	µg/kg
2007-4	RF1	3	Copper rockfish	Muscle	PCB 180	0.2	µg/kg
2007-4	RF1	3	Copper rockfish	Muscle	PCB 183	0.1	µg/kg
2007-4	RF1	3	Copper rockfish	Muscle	PCB 187	0.2	µg/kg
2007-4	RF1	3	Copper rockfish	Muscle	PCB 99	0.2	µg/kg
2007-4	RF1	3	Copper rockfish	Muscle	p,p-DDE	5.4	µg/kg
2007-4	RF2	1	Greenblotched rockfish	Muscle	PCB 101	0.1	µg/kg
2007-4	RF2	1	Greenblotched rockfish	Muscle	PCB 110	0.1	µg/kg
2007-4	RF2	1	Greenblotched rockfish	Muscle	PCB 118	0.1	µg/kg
2007-4	RF2	1	Greenblotched rockfish	Muscle	PCB 138	0.2	µg/kg
2007-4	RF2	1	Greenblotched rockfish	Muscle	PCB 149	0.1	µg/kg
2007-4	RF2	1	Greenblotched rockfish	Muscle	PCB 153/168	0.2	µg/kg
2007-4	RF2	1	Greenblotched rockfish	Muscle	PCB 187	0.1	µg/kg
2007-4	RF2	1	Greenblotched rockfish	Muscle	PCB 52	0.1	µg/kg
2007-4	RF2	1	Greenblotched rockfish	Muscle	PCB 99	0.2	µg/kg
2007-4	RF2	1	Greenblotched rockfish	Muscle	p,p-DDD	0.1	µg/kg
2007-4	RF2	1	Greenblotched rockfish	Muscle	p,p-DDE	4.1	µg/kg

Appendix D.3 *continued*

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	RF2	2	Greenblotched rockfish	Muscle	BHC, Gamma isomer	0.7	µg/kg
2007-4	RF2	2	Greenblotched rockfish	Muscle	PCB 105	0.1	µg/kg
2007-4	RF2	2	Greenblotched rockfish	Muscle	PCB 149	0.1	µg/kg
2007-4	RF2	2	Greenblotched rockfish	Muscle	PCB 153/168	0.5	µg/kg
2007-4	RF2	2	Greenblotched rockfish	Muscle	PCB 170	0.1	µg/kg
2007-4	RF2	2	Greenblotched rockfish	Muscle	PCB 187	0.2	µg/kg
2007-4	RF2	2	Greenblotched rockfish	Muscle	PCB 99	0.1	µg/kg
2007-4	RF2	2	Greenblotched rockfish	Muscle	p,p-DDE	9.2	µg/kg
2007-4	RF2	3	Mixed rockfish	Muscle	PCB 101	0.2	µg/kg
2007-4	RF2	3	Mixed rockfish	Muscle	PCB 105	0.1	µg/kg
2007-4	RF2	3	Mixed rockfish	Muscle	PCB 118	0.3	µg/kg
2007-4	RF2	3	Mixed rockfish	Muscle	PCB 138	0.4	µg/kg
2007-4	RF2	3	Mixed rockfish	Muscle	PCB 149	0.1	µg/kg
2007-4	RF2	3	Mixed rockfish	Muscle	PCB 151	0.1	µg/kg
2007-4	RF2	3	Mixed rockfish	Muscle	PCB 153/168	0.5	µg/kg
2007-4	RF2	3	Mixed rockfish	Muscle	PCB 180	0.2	µg/kg
2007-4	RF2	3	Mixed rockfish	Muscle	PCB 183	0.1	µg/kg
2007-4	RF2	3	Mixed rockfish	Muscle	PCB 187	0.2	µg/kg
2007-4	RF2	3	Mixed rockfish	Muscle	PCB 99	0.1	µg/kg
2007-4	RF2	3	Mixed rockfish	Muscle	p,p-DDE	6.1	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	Alpha (cis) Chlordane	7.2	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 101	15	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 105	5.5	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 110	9.2	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 118	24	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 119	0.9	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 123	2.5	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 128	6.3	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 138	34	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 149	9.2	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 151	5.8	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 153/168	55	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 158	1.9	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 170	7	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 177	4.3	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 180	23	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 183	6.7	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 187	26	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 194	5.3	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 201	7.6	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 206	2.1	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 28	1.1	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 49	2.3	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 52	4	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 66	3.3	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 70	3.1	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 74	2.1	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 87	3.6	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	PCB 99	19	µg/kg

Appendix D.3 *continued*

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	TFZONE1	1	Pacific sanddab	Liver	Trans Nonachlor	16	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	o,p-DDE	7	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	p,-p-DDMU	13	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	p,p-DDD	6.3	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	p,p-DDE	440	µg/kg
2007-4	TFZONE1	1	Pacific sanddab	Liver	p,p-DDT	5.4	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 101	2.7	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 105	2.1	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 110	2.3	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 118	8.900	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 128	2.8	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 138	14	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 149	1.1	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 151	2	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 153/168	22	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 158	1.2	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 170	4.4	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 177	1.4	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 180	12	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 183	3.1	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 187	9.7	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 194	3.4	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 201	3.4	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 206	1.7	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 49	0.5	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 52	1.1	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 66	1	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 70	1	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 74	0.7	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	PCB 99	5.6	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	Trans Nonachlor	3.2	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	p,-p-DDMU	3.4	µg/kg
2007-4	TFZONE1	2	Pacific sanddab	Liver	p,p-DDE	140	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 101	9.800	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 105	2.8	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 110	4.7	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 118	8.800	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 138	14	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 149	7.7	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 151	3.1	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 153/168	22	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 158	1.2	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 170	4.5	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 177	3.3	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 180	10	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 183	3.4	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 187	11	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 194	4	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 201	4.5	µg/kg

Appendix D.3 *continued*

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	TFZONE1	3	English sole	Liver	PCB 206	2.6	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 49	1.6	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 52	1.9	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 66	2.1	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 70	1.6	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 74	1	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 87	2	µg/kg
2007-4	TFZONE1	3	English sole	Liver	PCB 99	7.2	µg/kg
2007-4	TFZONE1	3	English sole	Liver	Trans Nonachlor	3.2	µg/kg
2007-4	TFZONE1	3	English sole	Liver	o,p-DDE	3.1	µg/kg
2007-4	TFZONE1	3	English sole	Liver	p,-p-DDMU	4	µg/kg
2007-4	TFZONE1	3	English sole	Liver	p,p-DDD	2.9	µg/kg
2007-4	TFZONE1	3	English sole	Liver	p,p-DDE	120	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	Alpha (cis) Chlordane	4.6	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 101	7.1	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 105	3.4	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 110	5.8	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 118	12	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 123	1.5	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 128	4	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 138	19	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 149	3.3	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 151	3.5	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 153/168	26	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 158	1.2	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 170	4.8	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 177	2.8	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 180	13	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 183	4.1	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 187	13	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 194	3.1	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 201	4.5	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 206	1.8	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 49	1.7	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 52	2.6	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 66	1.8	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 70	2.2	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 74	1.3	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 87	2	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	PCB 99	8.400	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	Trans Nonachlor	7.9	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	o,p-DDE	4	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	p,-p-DDMU	15	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	p,p-DDD	3.8	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	p,p-DDE	320	µg/kg
2007-4	TFZONE2	1	Pacific sanddab	Liver	p,p-DDT	6.5	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	Alpha (cis) Chlordane	6	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 101	8.800	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 105	4	µg/kg

Appendix D.3 *continued*

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 110	6.8	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 118	15	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 123	2.1	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 128	3.8	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 138	21	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 149	5.6	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 151	3.7	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 153/168	31	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 158	1.4	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 170	4.5	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 177	3.2	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 180	12	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 183	3.2	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 187	14	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 194	2.9	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 201	4.1	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 206	1.6	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 49	2.2	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 52	3.8	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 66	2.4	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 70	2.7	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 74	1.5	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 87	2.6	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	PCB 99	12	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	Trans Nonachlor	9.300	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	o,p-DDE	5.6	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	p,-p-DDMU	18	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	p,p-DDD	5.5	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	p,p-DDE	410	µg/kg
2007-4	TFZONE2	2	Pacific sanddab	Liver	p,p-DDT	7.1	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	Alpha (cis) Chlordane	6.2	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 101	8.5	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 105	4.4	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 110	7.6	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 118	15	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 123	1.9	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 128	4.8	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 138	28	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 149	5.6	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 151	3.7	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 153/168	42	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 158	2.6	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 170	7.7	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 177	2.5	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 180	18	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 183	5.6	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 187	18	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 194	4.5	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 201	5.5	µg/kg

Appendix D.3 *continued*

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 206	2.5	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 49	2.1	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 52	3.6	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 66	2.2	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 70	2.5	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 74	1.5	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 87	2.3	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	PCB 99	11	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	Trans Nonachlor	7.7	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	o,p-DDE	4.5	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	p,-p-DDMU	16	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	p,p-DDD	4.4	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	p,p-DDE	360	µg/kg
2007-4	TFZONE2	3	Pacific sanddab	Liver	p,p-DDT	5.4	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	Alpha (cis) Chlordane	5.6	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 101	41	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 105	28	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 110	56	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 118	110	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 119	4.3	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 123	9.2	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 128	27	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 138	130	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 149	15	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 151	16	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 153/168	150	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 156	13	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 157	3.4	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 158	12	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 167	6.2	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 170	15	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 177	6.5	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 180	29	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 183	9.5	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 187	31	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 194	4.9	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 201	6.1	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 206	2.9	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 44	2	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 49	8.2	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 52	17	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 66	8.400	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 70	4.8	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 74	4.6	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 87	12	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	PCB 99	83	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	Trans Nonachlor	9.800	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	o,p-DDE	4.5	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	p,-p-DDMU	15	µg/kg

Appendix D.3 *continued*

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	TFZONE3	1	Pacific sanddab	Liver	p,p-DDD	5.7	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	p,p-DDE	430	µg/kg
2007-4	TFZONE3	1	Pacific sanddab	Liver	p,p-DDT	7.4	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	Alpha (cis) Chlordane	6.1	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	BHC, Beta isomer	4.4	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 101	20.5	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 105	8.95	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 110	20	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 118	35	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 119	1.4	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 123	3.25	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 128	8.150	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 138	48.5	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 149	14	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 151	8.050	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 153/168	69	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 158	3.65	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 170	9.1	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 177	5.6	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 180	26	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 183	7.15	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 187	27	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 194	5.7	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 201	6.4	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 206	3.05	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 44	2.4	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 49	5.75	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 52	8.800	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 66	5.05	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 70	5.35	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 74	2.7	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 87	5.5	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	PCB 99	23	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	Trans Nonachlor	8.2	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	o,p-DDE	3.7	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	p,-p-DDMU	12	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	p,p-DDD	4.65	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	p,p-DDE	315	µg/kg
2007-4	TFZONE3	2	Pacific sanddab	Liver	p,p-DDT	4.5	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	Alpha (cis) Chlordane	5	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	BHC, Beta isomer	3.3	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 101	9.5	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 105	3.2	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 110	6.2	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 118	13	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 123	1.4	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 128	2.7	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 138	15	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 149	5.2	µg/kg

Appendix D.3 *continued*

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 151	3.4	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 153/168	27	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 156	1.8	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 158	1.1	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 170	4.2	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 177	2.1	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 180	10	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 183	3	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 187	11	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 194	2.5	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 201	3.2	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 206	1.4	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 44	1.2	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 49	2.5	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 52	3.6	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 66	2	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 70	2.5	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 74	1.2	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 87	2	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	PCB 99	8.7	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	Trans Nonachlor	6.7	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	p,-p-DDMU	10	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	p,p-DDD	3.5	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	p,p-DDE	220	µg/kg
2007-4	TFZONE3	3	Pacific sanddab	Liver	p,p-DDT	3.5	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	Alpha (cis) Chlordane	5.4	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 101	7	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 105	3	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 110	4.2	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 118	11	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 123	2	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 138	16	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 149	4.2	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 151	2.4	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 153/168	25	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 156	1.7	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 158	1.2	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 170	3.8	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 177	1.7	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 180	9.6	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 183	2.7	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 187	10	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 194	2.2	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 201	2.9	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 206	1.2	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 49	1.5	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 52	2.7	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 66	1.5	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 70	2.1	µg/kg

Appendix D.3 *continued*

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 74	1	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	PCB 99	5.6	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	Trans Nonachlor	7.9	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	o,p-DDE	2.5	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	p,-p-DDMU	9.300	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	p,p-DDD	2.8	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	p,p-DDE	220	µg/kg
2007-4	TFZONE4	1	Pacific sanddab	Liver	p,p-DDT	4.7	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	Alpha (cis) Chlordane	8.5	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 101	9.1	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 105	4.2	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 110	6.6	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 118	16	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 123	2.4	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 128	5.1	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 138	26	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 149	6.6	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 151	4.8	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 153/168	45	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 156	2.2	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 158	2.4	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 170	6.5	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 177	4.2	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 180	17	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 183	4.6	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 187	17	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 194	3.8	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 201	4.4	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 206	2.1	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 44	1.2	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 49	2.5	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 52	3.1	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 66	2	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 70	2.3	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 74	1.5	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	PCB 99	10	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	Trans Nonachlor	8.7	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	o,p-DDE	2.9	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	p,-p-DDMU	14	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	p,p-DDD	4.8	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	p,p-DDE	360	µg/kg
2007-4	TFZONE4	2	Pacific sanddab	Liver	p,p-DDT	5.7	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	Alpha (cis) Chlordane	6.2	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 101	7.2	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 105	2.9	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 110	4.7	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 118	11	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 128	2.4	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 138	13	µg/kg

Appendix D.3 *continued*

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 149	4.5	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 151	2.8	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 153/168	26	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 158	1.2	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 170	4.7	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 177	2.1	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 180	11	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 183	2.8	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 187	11	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 194	2.8	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 201	2.6	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 206	1.5	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 49	2	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 52	2.9	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 66	1.9	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 70	2.1	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 74	1.5	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	PCB 99	6.9	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	Trans Nonachlor	7.5	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	o,p-DDE	3.7	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	p,-p-DDMU	14	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	p,p-DDD	5.8	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	p,p-DDE	250	µg/kg
2007-4	TFZONE4	3	Pacific sanddab	Liver	p,p-DDT	7.1	µg/kg